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Thesis:

Element Analysis of the Green Building Process

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Thesis submitted in partial fulfillment of the requirements of the degree of Masters of Science in Environmental, Health & Safety Management.

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Abstract

This thesis studied the definition of a green building and the elements associated with the construction of single family home versus an office building. There are many rating systems available across the Country both private and public. The most well known is the LEED rating system developed by the United States Green Building Council. LEED has several rating programs now available. The eight elements of LEED for Homes are used as the basis of the research to create commonality throughout the documentation.

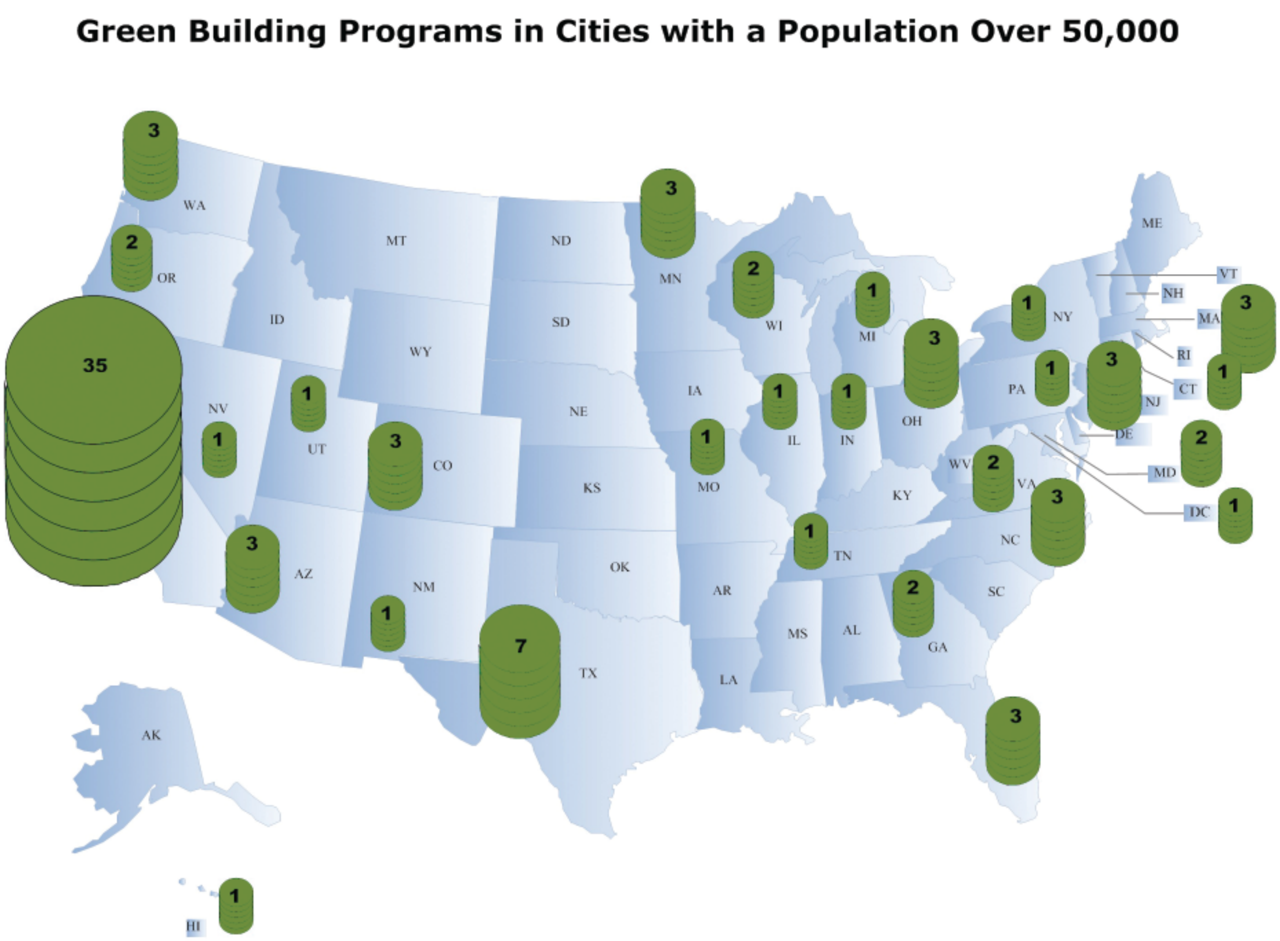
Thirty single-family homes and office projects were examined and detailed in order to determine the aspects within each of the eight elements that define the project based on the definition of green. The elements include innovation and design, location and linkages, sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality and awareness and education. The more significant focus in the construction projects examined is on water use and energy. This is not a surprising outcome considering the cost and availability of energy and water supplies.

Perhaps there are two significant main points that the research has provided, first the education of the general public about sustainability and its impact on a global scale. The second point from the research is the need for a holistic approach to building a green structure. A holistic approach includes the design, construction and operation of the building. Often times green features are an afterthought, resulting in the green aspects not being as effective

1.0 Introduction

The purpose of this research is to complete an analysis of the elements of a green office building and a single-family home. This is also known as sustainable, green buildings which represent friendly structures that significantly reduce their impact on the environment. This topic becomes more relevant as the cost for energy and natural resources continue to increase. The 2007 American Institute of Architects, *Study of Green Building Programs in Our Nation's Communities*, states that over 107 million Americans live in communities with green building policies (based on cities with a population of over 50,000,) see figure 1.

Figure 1



Buildings account for the largest source of energy consumption in America, an estimated 43 percent of all greenhouse emissions compared to 32 percent for transportation and 25 percent for industry. In light of these numbers, the design and construction of green buildings presents an opportunity to rectify this imbalance.[1]

The elements used in making a structure green are an important aspect of determining the benefit of the more sustainable building. “Element” is defined as the practice and use of construction principles that make a building efficient with regard to the use of resources. The word element can also include the impact of the cost resources have on the owner and surrounding community. This topic is worthy of study because it allows the creation of understanding the similarities and differences of becoming green and the associated impacts on an office building and the single-family home. The understanding of a green structure instills the importance in taking the use of resources and their impacts to society under consideration. The use of resources and the impacts becomes especially relevant where the impact occurs to humans, the natural wildlife both flora and fauna, and the future generations.

A green building is one that is designed to reduce or eliminate the impact on human health and the natural environment. This is accomplished by incorporating materials and operational elements that are environmentally responsible and resource efficient throughout the life cycle of the building.[2] How “Green,” a building can become depends upon the number of the incorporated elements that are used and their associated impact to the human health and the environment. A more detailed discussion of a green building is discussed in the literature review chapter.

The life cycle of a green building is an aspect that is also drawing more attention as it has an even broader impact on the community. The life cycle of a green building is defined as the life expectancy of any components that make up the structure and impact on the operation of the structure over an established period of time. Life cycle can also consist of the overall impact to society in terms of a green environmentally friendly building and any associated environmental contributions that may be made. Owning a green home and providing the environmental benefits are somewhat negated when the owner drives a gas consuming vehicle that adds pollutants to the atmosphere. Another good example is the homeowner who claims not to use fertilizers or pesticides but hires a landscaper to do it. All these activities together can negate the benefits of the green building and have an impact on the community and indeed to society as well.

An important aspect of a green structure is its “Carbon Footprint.” A carbon footprint is the release of carbon dioxide from energy use. Energy use includes that used for the manufacture and harvest of products used in construction of a building. This use also includes the energy used in the operation of a building such as heating, cooling, lights as well as other aspects. The use of carbon foot printing is new to the building industry and has only recently started to be used as part of the design and operational efficiency.

In the past the trend in building green has been more focused on the building itself, but is now leaning more toward a whole approach to include a perspective of the greater community and the global impact. The design starts early and considers such factors as location in reference to public transportation, proximity to employment, schools, shopping as well as other aspects. Is the building being constructed on virgin land or can it be built on land already in use? Can existing on-site resources be used in some aspect of construction? The importance in early design is to build in consideration of the more global impact both short and long term. It is important to consider as many impacts as possible that resource use can have of the greater community.

1.1 Focus

The research examined criteria used in the decision-making of the elements for determining green construction for an office and single-family home. A rating system called LEEDS (Leadership in Energy and Environmental Design) developed by the United States Green Building Council (USGBC) and the newly developed rating system from the National Home Builders Association (NAHB) is utilized as the basis for this research. Research conducted for this thesis, looked at existing buildings that have been successfully completed and examined the criteria used in making them green. From the information collected, a database utilizing existing projects for the single-family home and office building green projects was created. A survey was completed of the green building process including the certification aspects. The survey utilizes published articles, standards, codes and regulations pertaining to the green elements used for commercial and home construction. The survey delineates the commonalities between the green home and office building.

The criteria used in making a structure green are examined and described in detail as aprt of the completed survey. Is the criterion different between an office building and that of a single-family home? A discussion of the certification processes used around the Country is provided as a basis for defining a green structure.

1.2 Deliverable

The final product defines what the green parameters are and describes commonalities between them. A database has been created that includes the criterion collected. The data is included in chapter 6 and forms the basis for the minor analysis located in the last chapter of this thesis.

1.3 Definitions

Carbon Footprint – is defined as the measure of the exclusive global amount of carbon dioxide (CO2) and other greenhouse gasses emitted by a human activity or accumulated over the full life cycle of a building. 3

High-Performance Building – is defined as a structure that is energy efficient has low-term and long-term life-cycle costs, is healthy for its occupants, and has relatively low impact on the environment. 4

HVAC – (Heating, Venting, and Air Conditioning) – refers to the equipment, distribution network, and terminals that provide either collectively or individually the heating, ventilating, or air conditioning processes for a building.

VOC- volatile organic compounds – building materials can contain solvents when emitted impact atmospheric ozone.

1.4 Terms used in this thesis

USDOE – United States Department of Energy

USGBC - United States Green Building Council

USEPA – United States Environmental Protection Agency

LEED - Leadership in Energy and Environmental Design

ASHRAE – American Society of Heating, Refrigerating and Air-conditioning Engineers

NAHB - National Association of Home Builders

2.0 Background

"Green," or "Going Green," is a term that is becoming very common today and be defined differently depending on the aspect. Green can be used to reference how products are made or what make up a product. Green can be said to be interchangeable with sustainability in that by reducing the demand on natural resources society will be assured a place in the global future. Community recycling programs can be considered green. An industrial facility can go green by recycling waste or not generating any altogether. Defining green can sometimes be a difficult task, because "green" can mean different things to different people. "Green" also has had different meanings during human presence on this planet. Adam Adamson, Managing Director at Landor Associates of New York said it well:

> "Is it about the environment, organic food or 'good-for-you' living … It could be all of those things. It is easy to say you are green, but consumers are skeptical. And because everyone wants to jump on the green bandwagon, all of a sudden it is noisy in this space, and it is hard to break through."[5]

Green is a subset of sustainability and has many definitions. One definition of green that fits the theme of this thesis is:

> "…green or sustainability design," the one most commonly used looks at meeting the needs of the present without compromising the ability of future generations to meet their needs."[6]

Building a green structure is a subset of sustainability, a part of a larger group of activities that together will help future generations meet their needs.

Construction and operation of buildings large and small can be green. One could say society is in a "New Green Revolution." Green revolutions in the past have pertained to agriculture and were often referred to as the "Green Revolution." The new green revolution now refers to making buildings and communities environmentally friendly in order to provide sustainability for the future.

This thesis will focus on a smaller subset of the sustainability issue, the green office and single family home.

Green buildings have been around for a very long time. Today, the concept of an energy efficient building is at least known by most people. Yet most people in society do not understand what green really means to everyday living. The culture in the United States has become very accustomed to throwing away and buying new (disposable economy) with little regard to the resources. One could generalize that Americans have become used to paying for convenience and until the cost of doing so becomes too prohibitive, people will continue. This trend is beginning to change as the cost for natural resources becomes ever more expensive. Sustainable resources will be impacted by more than mass transit and alternate energy sources. Although these are important, the practice of building green also has a significant impact on the resources used today.

Many standards and guidelines have been developed worldwide for green building. Some examples as listed in Wikipedia, Green Building include[7]:

- Code for Sustainable Homes, United Kingdom
- Green Building Council, Australia www.gbcaus.org, Australia
- Green Globe, www.greenglobe.com, USA, Canada
- Leadership in Energy and Environmental Design (LEEDS) is used in a number of different countries.

Communities are developing green construction standards in order to improve upon and extend resources for future generations. In addition to these standards, there has been an increase in the construction of green office buildings and homes.

3.0 Literature Review

3.1 Background

One important aspect of the green building includes the market for this type of structure. The demand has increased in the last decade and is expected to continue to do so. LEED (Leadership in Energy and Environmental Design) registered public sector green buildings have increased 10 percent while commercial buildings have increased 5 percent of the annual construction market.[8] LEED registered buildings are only part of the green construction movement.

There are a number of building councils, associations and government sponsored initiatives that support the construction of green buildings. Together an improved understanding of the green building and construction requirements are being formed. The literature search has only uncovered a fraction of available information that will better define and support the design and construction of a green building. The focus of the literature review at this point is to uncover the accepted definition of a green building and the most prevalent criterion used in the design and construction.

3.2 Current Issues and Trends

3.2.1 Defining a Green Building

An important concept in approaching this thesis is defining a green building. The California Integrated Waste Management Board defines a green building as, "A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment."[9] Jerry Yudelson, in "The Green Building Revolution," describes a green building as, "…a high-performance property that considers and reduces its impact on the environment and human health."[10] The Massachusetts Technology Collaborative Renewable Trust, defines a green building as, "…a building that has been constructed or renovated to incorporate design techniques, technologies, and materials that minimize its overall environmental impacts." [11]

The definitions of a green building will sometimes include a description of a high-performance building. A high-performance building while similar to a green building specifically aims to be energy efficient. High-performance buildings and there design are an all-inclusive philosophy taking into consideration the interaction of the whole building structure and systems.[12] The United States Department of Energy has developed criteria for high-performance buildings and started a project called "Commercial High-Performance Buildings," the goal is to apply design into construction principles.

The United States Environmental Protection Agency (USEPA) has a vested interested in green buildings just by the nature of its responsibility to protect the environment. This responsibility includes the support for the green building concept. The USEPA definition of a green building is:

> "Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building."
>
> "Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:
>
> - Efficiently using energy, water, and other resources
> - Protecting occupant health and improving employee productivity

- Reducing waste, pollution and environmental degradation

For example, green buildings may incorporate sustainable materials in their construction (e.g., reused, recycled-content, or made from renewable resources); create healthy indoor environments with minimal pollutants (e.g., reduced product emissions); and/or feature landscaping that reduces water usage (e.g., by using native plants that survive without extra watering)." [13]

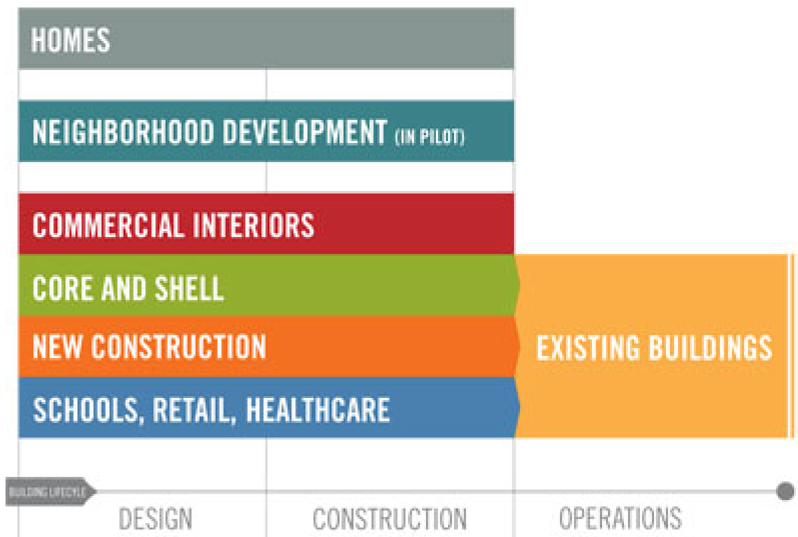
3.2.2 Building Councils

There is a number of building councils and associations across the United States. The main focus of this thesis is the study of available information as it pertains to the criteria used in the construction of an office building and the single-family home. The literature search has lead to two significant sources that provide certification and guidance in the design and construction of green buildings. The Green Building Council and the National Association of Home Builders is the central focus of the literature review.

3.2.2.1 The Green Building Council and Leeds

The United States Green Building Council (USGBC) was founded in 1993 for the main purpose of driving the change of sustainability in the construction of buildings. Originally USGBC was organized as a committee of like-minded people coming together to form a consensus on the creation of sustainable building. The committee recognized the need to educate members of their own profession on how to create a sustainable building. The ultimate goal of LEED's was to impact a market transformation. In 2000, LEED was launched. LEED encourages adoption of sustainable green building and development practices. The LEED creators understood that for a green building to become viable, their clients would have to understand what advantages building green would have for them in terms of life-cycle costs, productivity increases and the ability to market the buildings.[14] This is accomplished through implementation of tools and performance criteria. LEED is a certification program that has become nationally accepted as a way to prove a building is green. The reason for wanting a green building was discussed in the previous section.

Rating systems programs have been developed by the USGBC for different types of buildings, Figure 2, each with their own criterion.



LEED rating systems that have been developed[15]

Figure 2

Each program rating system has an individual checklists and USGBC certification. These include:

- New Construction – designed to guide and distinguishes high-performance commercial and institutional projects.
- Existing Buildings – provides a benchmark for building owners and operators to measure operations, improvements and maintenance.
- Commercial Interiors – is a benchmark for the tenant improvement market that gives the power to make sustainable choices to tenants and designers.

- Core & Shell – aids designers, builders, developers and new building owners in implementing sustainable design for new core and shell construction.
- Schools – recognizes the unique nature of the design and construction of K-12 schools and addresses the specific needs of school spaces.
- Retail – recognizes the unique nature of retail design and construction projects and addresses the specific needs of retail space.
- Healthcare – promotes sustainable planning, design and construction for high-performance healthcare facilities.
- Homes – promotes design and construction of high-performance green homes.
- Neighborhood Development – integrates the principles of smart growth, urbanism and green building.

To receive a LEED certification a building must meet the criteria for that particular type of structure in the appropriate program. This thesis will discuss the LEED programs for new construction and homes. As previously stated, the original program started by LEED-NC in 2000 was for new construction. New construction program guidelines cover six categories:

- Sustainable sites – Reduce pollution from construction activity, avoid development of inappropriate sites and reduce the environmental impacts of the location on the building at the site. Sustainable can also be in reference to alternative transportation, impacts from light pollution and heat island effect.
- Water efficiency- Limit or eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the site, for landscaping, and innovation in the use of wastewater technologies, and other use reduction.
- Energy and atmosphere – Verify that the energy related systems are installed, and performing according to the project design, establishment of minimum energy

efficiency, reduce ozone depletion, increase use of renewable energy, provide for ongoing accountability of energy consumption over time and encourage development of renewable energy technologies on a near zero pollution basis.

- Materials and resources – Storage and collection of recyclables by the occupant, divert construction waste material from landfill disposal, use of existing building materials, use of local and recycled (pre and post consumer) materials, reduce or not use finite raw materials in the construction material of the building and encourage environmentally responsible forest management.
- Indoor environmental quality – Establishment of indoor air quality performance as it pertains to the comfort and well-being of the occupants from any hazardous particles or chemical pollutants, or biological impacts. Provide lighting, heating and cooling comfort for the occupants.
- Innovation and design process – Encourage for design and implementation of components that go above the minimum LEED requirements.

LEED uses a point based-rating system. Points are given for each criterion that has been met. Each of the six categories in the New-Construction program has sub-categories that are assigned points adding to a possible score of up to 69 points. LEED then adds the points and issues a rating level. The rating system for New Construction is:

- Certified – the project scored 26 to 32 points of the core points.
- Silver rating – the project scored 33 to 38 points.
- Gold rating – the project scored 39 to 51 points.
- Platinum rating - the project scored more than 69 points.

Earning points for any of the programs is accomplished by meeting the criterion established for the particular category within the given program. An example of the point system is the sustainable sites category for New Construction. In this category, there are eight credits and one prerequisite. The prerequisite must be met before a building can be certified. The prerequisite, for construction-activity pollution prevention, is required in order to even consider certifying a building under the LEED program. The reason for this prerequisite is to ensure that construction waste, erosion, and runoff do not contaminate adjacent sites or the overall environment. Points are not given for meeting a prerequisite. The points in the sustainable-sites category include alternative transportation (such as access to public transportation), brownfield redevelopment (cleaning up a contaminated site, as opposed to using a "Greenfield," which has never been built on), light pollution reduction, and mitigation of the heat-island effect.[16]

Other credits work in a similar way. For example, water-efficiency credits look at ways to handle wastewater, the reduction of irrigation for landscaping, and waste-use reduction. Energy and atmosphere requires some fundamental building commissioning, minimum energy performance, and reduction of chlorofluorocarbons in mechanical systems, but it also encourages the use of renewable-energy strategies.[15]

The LEED Home Program measures overall performance in eight categories:

- Innovation & Design Process –Special design methods, unique regional credits, measures not currently addressed in the rating System, and exemplary performance levels.
- Location & Linkages – The placement of homes in socially and environmentally responsible ways in relation to the larger community.
- Sustainable Sites – The use of the entire property so as to minimize the project's impact on the site.
- Water Efficiency – Water-efficient practices, both indoor and outdoor.

- Energy & Atmosphere – Energy efficiency, particularly in the building envelope and heating and cooling design.
- Material & Resources – Efficient utilization of materials, selection of environmentally preferable materials, and minimization of waste during construction.
- Indoor Environmental Quality – Improvement of indoor air quality by reducing the creation of and exposure to pollutants.
- Awareness & Education - The education of homeowners, tenant, and/or building manager about the operation and maintenance of the green features of a LEED home.

The rating system for LEED Home Construction is:

- Certified – the project scored 45 to 59 points of the core points.
- Silver rating – the project scored 60 to 74 points.
- Gold rating – the project scored 90 to 136 points.
- Platinum rating - the project scored more than 136 points.

LEED for Homes allow home size adjustments based on the square footage. This also allow for larger homes and multi-family units that use more resources. Like the LEED New Construction, the Home Program does have prerequisites. In the sustainable sites category prerequisites are required for erosion control during construction. For example, there is a specific list of specific erosion control measures that must be met:

- Stockpile and protect disturbed topsoil for possible reuse.
- Control the path and velocity of runoff with silt fencing.
- Protect on-site storm sewer inlets, streams, and lakes with straw bales, silt fencing, silt sacks, rock filters, or comparable measures.
- Protect swales to divert surface water from hillsides.

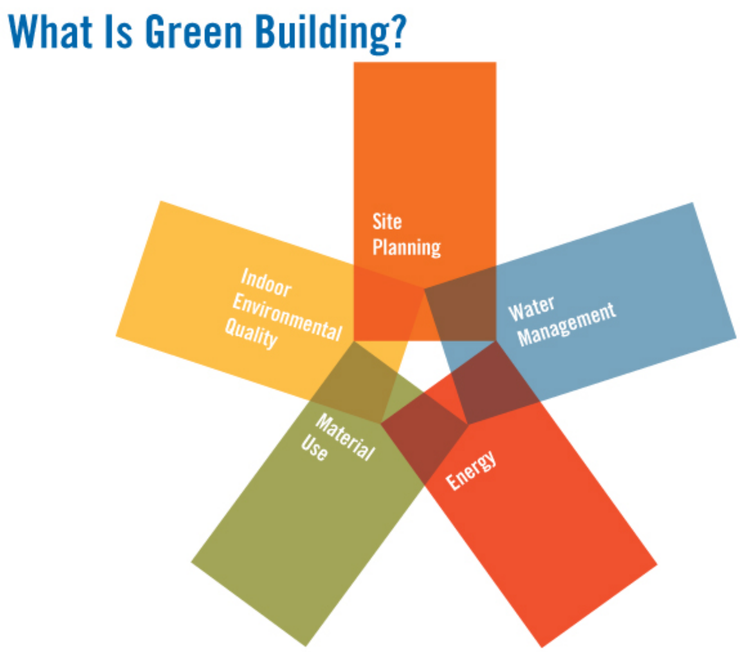
- If soils in a sloped area are disturbed during construction, use ties or a comparable approach to stabilize the soil.

Another sustainable site prerequisite includes no invasive plant species can be introduced into the landscaping.

There are no prerequisites for water efficiency; however energy and atmosphere category must meet the performance of Energy STAR for Homes, including third party inspections. Other energy and atmosphere prerequisites include requirements for: basic insulation, reduced envelope leakage, window design and installation, heating and cooling system, lighting, and residential refrigeration.[17]

The USGBC defines green (see Figure 3) as a “high performance building that’s energy and water efficient, has good indoor air quality, uses environmentally sustainable materials and also uses the building lot or site in a sustainable manner.”[18]

Figure 3



This graphic describes the LEED definition of a green home very well and is taken from the U. S. Green Building Council web site located at www.usgbc.org/DisplayPage.aspx?CMSPage ID=1720

3.2.2.2 National Association of Home Builders

The National Home Builders Association (NAHB) was founded in 1942 and is a federation of more than 800 state and local associations[19]. The mission of NAHB is to enhance the climate for housing and the building industry. One of the chief goals is proving and expanding opportunities for all consumers to have safe, decent and affordable housing. The NAHB serves a number of different functions within the organization including influencing legislation, public education and building criteria among others.

The NAHB has developed a program called, *NAHB Model Green Home Building Guidelines.* The guidelines were designed with the home builder in mind. As stated in the introduction, “The main purpose of the guidelines is to highlight ways in which the mainstream home builder can effectively and holistically weave environmental concerns into a new home and to provide a tool for local associations to create a green home building program." The guidelines list guiding principles that are to be taken under consideration when building a green home[20]:

1. Lot Design, Preparation, and Development – Even before the foundation is poured, careful planning can reduce the home's impact on natural features such as vegetation and soil; and enhance the home's long-term performance. Such preparation can provide significant value to the homeowner, the environment, and the community. These reduce environmental impacts and improve energy performance of a new home. As an example savings trees already on-site and constructing onsite storm water retention/infiltration features and orienting houses to maximize passive solar heating and cooling are basic processes used in the design and construction of green homes.
2. Resource Efficiency – Consideration of the environment in the design phase – the time, at which material selection occurs, leads to a more successful green home. Advanced framing techniques and home designs can effectively optimize the use of building materials. Creating resource efficient design and use of efficient materials can maximize function of the home while optimizing the use of natural resources. For example engineered wood products can optimize resources by using materials in which more than 50% more of the log is converted into structural lumber, thereby reducing the need for resources.
3. Energy Efficiency – minimizing the environmental impacts of energy used in the construction, operation of the home and in the making of the construction materials.
4. Water Efficiency – the implementation of water conservation measures that will reduce the impact on natural water resources, storm water and wastewater treatment.
5. Indoor Environmental Quality – creation of healthy and safe indoor air is important in a green building. Indoor air quality is often cited as the second most important feature of a

green home after energy use. More important attention is being paid to the type of building material used and the potential impact to the occupants of the home.

6. Operation, Maintenance and Homeowner Education – improper maintenance can defeat the efforts to create a resource efficient home. As an example a home owner may fail to change air filters regularly or not operate kitchen or bathroom exhaust air to remove excess moist air. These impacts the air quality of the home and excess moisture can create mold that can impact the health of the occupants.

   An education program that provides information to the homeowner on how to maintain and operate a green home is provided. A manual on how to optimally operate and maintain the house is provided to the homeowner.

7. Global Impact – this guiding principle does not fit neatly into the context of green home building but has a global impact. By-products from the construction and operation of the green home such as volatile organic compounds can have an impact on ozone. This is a global issue not just confined to the community.

8. Site Planning and Land Development – consideration to the entire community and existing infrastructure in addition to the individual building can amplify the benefits of green home building. As an example the improvement of a subdivision’s storm water management plan and preserving the available natural surroundings through careful design and construction, can impact the entire community and reduce infrastructure costs.

There are three levels for builders to rate their projects: bronze, silver or gold. Points are assigned for each line item on a checklist that meets the established criteria. The higher the rating the more green the home. There are seven guiding principles that are used to ensure that all aspects of green building are addressed and that there is a balance with the whole house approach. The point system used by the NAHB as shown in Table 3.1[21]

Table 3.1

	Bronze	Silver	Gold
Lot Design, Preparation, and Development	8	10	12
Resource Efficiency	44	60	77
Energy Efficiency	37	62	100
Water Efficiency	6	13	19
Indoor Environmental Quality	32	54	72
Operation, Maintenance, and Homeowner Education	7	7	9
Global Impact	3	5	6
Additional points from sections of your choice	100	100	100

3.2.3 EarthCraft House Program

The EarthCraft House program is a voluntary green building program and serves the Southeast region of the United States. In 1999, the Greater Atlanta Homebuilders Association and the Southface Energy Institute came together and created the EarthCraft Housing Program. In 2004, the EarthCraft program expanded and covers much of the Southeast to include Alabama, South Carolina, Georgia, Tennessee, and Virginia. EarthCraft certifies both single-family and multi-family homes through an approval process. A builder must first complete a worksheet to show that the home will score enough points to qualify for the certification. The house is then inspected and tested by EarthCraft using an independent third party.

To become EarthCraft House certified a house must score a minimum of 150 points on the scoring worksheet. There are separate worksheets used for scoring single-family, multi-family homes, and home renovation. The worksheet lists the required criteria and the points that each is worth. In addition to the point requirement each house must have plans on orientation, meet ENERGY STAR certification criteria, have a Pre-drywall inspection by an EarthCraft House inspector, and pass a final inspection by EarthCraft. Select and Premium status are awarded to homes that meet additional criteria and achieve 200 and 230 points. All EarthCraft certified homes are also awarded ENERGY STAR certification. Points can be earned in ten different categories[22]:

1. Site Planning – includes an erosion control plan, tree preservation plan (builder must participate in the Building with Trees Program), and when possible a wildlife habitat area.
2. Energy Efficient Building Envelope and Systems – consists of a thermal barrier and an air barrier. The Home must meet the requirements and become compliant with the requirements of the Energy Star guidelines as set forth by the U.S. Environmental Protection Agency.
3. Resource Efficient Design – framing design must comply with local building codes.
4. Resource Efficient Building Materials – construct the house from at least 50% lumber that meets the criteria of sustainable harvesting as set forth by the Forestry Stewardship Council (FSC). Requirements for engineered floor framing, recycled content of outdoor structures must be at least 40%, singles and exterior roofing must have a minimum 25-years manufacturers' warranty.
5. Waste Management – no construction materials shall be burned or buried on the job site or other area except state approved construction and demolition landfill. A construction waste management plan must be submitted. A minimum of 75% recycling is required including wood product.
6. Indoor Air Quality – all combustion units must be vented, moisture control is required for the construction materials such as plastic footing wraps. Bathroom and dryer venting is required, as is a passive radon vent system, and urea-formaldehyde is not allowed in any construction materials.

7. Water Conservation (Indoor and Outdoor) – all fixtures will meet the National Energy Policy Act low flow standards. Each home will comply with the Water Smart Program for example a greywater irrigation plan and a rainwater harvest system will be included.
8. Homeowner Education – the builder must provide a manual and review with the homeowner the features of the green home.
9. Builder Operations – these are builder only requirements, but include an agreement to build and certify one EarthCraft House every year.
10. Innovation Points – this category allows for bonus points if certain criteria is met, such as locating the home within 0.25 miles of mass transit, plant or preserve street trees every 40 feet or installation of a solar electric system.

3.2.4 Other Green Building Programs

There are a number of other green building programs across the country. There are numerous programs; attempting to regulate sustainable building it is noteworthy to mention a few of them. The main purpose of presenting them here is to show that other programs are available and in place in the United States. Listed here are some case studies as taken from the 2007 AIA report called *Local Leaders in Sustainability: A Study of Green Building Programs in Our Nation's Communities*. This study is of particular importance as it examines a cross section of community programs from across the Country. This enables an examination of green building programs on a local level.[23]

3.2.4.1 Portland, Oregon

The City of Portland adopted program called an *Action Plan for Portland* in 2000, although green building efforts began in 1994. This created the Green Building Division in the Office of Sustainable Development and the Green Investment Fund. A "G-Rated," or green-rated program was created whose primary purpose is to encourage owners and developers to use green building practices and to provide support to the community. One outcome from this effort is the requirement that all city buildings be rated LEED certified. The G-Rated program also provides residents with a resource for information on green building practices. The Green Investment Fund is a grant program established to support innovative designs for green building projects. The City of Portland provided $425,000 in grants in 2007. The Pearl District in Portland serves as a model for green urban development. This neighborhood is said to have the greenest buildings per square mile in the United States.[24]

3.2.4.2 San Francisco, California

The city of San Francisco adopted its first sustainable plan in 1997, while its green building ordinance has been in place since 2004. Initiatives undertaken by San Francisco include a 2002 Climate Action Plan, which commits to carbon reductions to 25percent of the 1990 levels by 2012. Municipal buildings of greater than 5,000 square feet are required to obtain a LEED silver certification. San Francisco has 50 green buildings already constructed including 7 public buildings, 20 commercial, and 2 multi-family and 20 single-family homes.

Additional sustainable initiatives include a Green Business Program that promotes energy and waste conservation. Tax deductions are also available for these businesses as long as they meet the Green Business standard. Also implemented is a Generation Solar to streamlines and promote the installation and use of solar power in residential applications. In 2005, Plaza Apartments was opened a nine-story apartment building that was built to green standards.

Future plans for the City of San Francisco include moving beyond basic green standards and including neighborhood and district design. Legislation is being drafted that would require that the construction of all commercial buildings meet LEED standards. This includes adoption of the Alameda County Build It Green guidelines for multi-family and single family homes.[25]

3.2.4.3 Scottsdale, Arizona

In 1996, the city of Scottsdale developed its first sustainable building initiative within the Cities building department. In 1997, an ad-hoc committee was formed to look at the high volume of residential construction taking place and how to integrate green building in that sector. This led to the development of the Scottsdale Green Home Rating Checklist. In 2007, the city reported that 1,223 green single-family and 20 multi-family homes have been completed. A residential checklist was created in 1998 that consists of two levels:

- Entry level – accumulating 50 – 99 points,
- Advanced level – score more than 100 points.

Points are awarded for structural elements; energy rating/performance; thermal envelope; heating, ventilation, and air conditioning; electrical power, lighting, and appliances; plumbing system; roofing; exterior, and interior finishes; interior doors, cabinetry, and trim; flooring; solid waste; and innovative design. The rating program has gone through several iterations to reflect changes to national programs.

Similar commercial standards were developed in 2001; the volunteer program copies the residential criteria. The City now requires all municipal buildings to be green. Beginning in 2003 all municipal buildings must meet LEED gold as a minimum standard. The city's senior center completed in 2006 was the first green building to meet this standard.[26]

3.2.4.4 Chicago, Illinois

There is no specific green building policy or sustainability plan; instead the city has created initiatives overseen by a sustainability director. The Chicago Standard is one standard in place that requires municipal buildings be at least LEED silver, and any commercial or multi-family projects receiving tax increment financing from the city be LEED certified. This standard requires that certain standards from the LEED guidelines be, such as erosion control, minimum energy performance be followed on all projects.

The city has a voluntary Green Permit Program. The three-tiered program rates projects on their greenness. The three levels are:

- Top tier- must achieve a LEED Gold rating for the building, one Chicago-specific item and a 50 percent green roof.
- Middle tier – must achieve a LEED Silver rating for the building, one Chicago-specific item and a 25 percent green roof.
- Third tier - must achieve a LEED Certified rating for the building, one Chicago-specific item and an Energy Star roof.

The Green Permit Program began to focus on the Chicago Bungalow in April 2007, as a way to preserve the traditional Chicago bungalows. It is estimated that the renovation of a bungalow increased the cost about 2 percent. The city is working to expand incentives for this new effort.

The Chicago Center for Green Technology serves as a resource and clearing house for green information for the public. The building is part of the cities green program and is used as an example by being able to reduce carbon emissions by greater than 50 percent. Guests can visit and explore the building to understand how a green building works. [27]

3.2.4.5 Austin, Texas

The city started the green program in 1991, growing out of the energy conservation program from the 1980s. The green program became Austin Energy in 1998 and includes residential, commercial and municipal construction. In 2000, the city required that all municipal buildings must meet LEED Silver standards. The program is voluntary, except for municipal building, and includes a rating system. The rating system is unique because it includes a mechanism that subtracts points for unsustainable features. Several thousand single-family homes have been rated on a five star system. The program rates homes is six areas: energy efficiency, testing, water efficiency, materials efficiency, health and safety, and community.

The commercial program focuses on helping professionals set realistic goals or green aspects of buildings such as energy and water use, indoor air quality, and pollution control. Assistance is provided in evaluating short and long term projects cost, methods to reduce construction and operation waste, select appropriate sites, and consider impacts and benefits of going green.

The city has established a climate protection plan requiring buildings run on 100 percent renewable energy by 2012 and be carbon neutral by 2020. New single-family homes will be zero net energy capable by 2015 and increase efficiency on all other construction by 75 percent by 2015.[28]

3.2.4.6 Atlanta, Georgia

Atlanta's green building program is voluntary. In 1999, the Greater Atlanta Homebuilders Association and the Southface Energy Institute came together and created the EarthCraft Housing Program. This is not a city program, and offers only recognition as an incentive. In 2003, the EarthCraft program collaborated with the Urban Land Institute and others to create the EarthCraft Communities Program. This program is a broad, sustainable community guideline and looks at the entire community to emphasize walkability, environmental site plan development, and an overall integrated planning approach. In 2004, the EarthCraft program expanded and now covers much of the Southeast to include Alabama, South Carolina, Georgia, Tennessee, and Virginia. Another unique feature of the EarthCraft program is its focus on low-income housing to show that green can be affordable, cost-effective, and save homeowners money. EarthCraft has worked with Habitat for Humanity and others to create affordable, green housing.

In 2003, Atlanta required that all municipal building become LEED Silver. Atlanta has seen very rapid growth and realized it needed to change from its unsustainable past to a green and smartly designed sustainable future. The BeltLine project is a 25-year effort to create sustainable communities in a belt line area one to three miles from downtown, impacting underused residential, commercial and industrial land.[29]

3.2.5 Building Principles

The first step in the construction of a green building is the initial design. Such factors as climate (for example; temperature, prevailing wind, weather patterns and most sun exposure), topography (hilly, soil and subsurface geography, location in a forested area and water bodies), location in rural, suburban or urban area, available natural resources (water, forest, geography, sun light, wind, and other building materials) and community (zoning, street design and utilities). The initial design is a holistic approach in that all the factors listed above are taken under consideration. Design also includes examining the most environmentally friendly and least ecologically obtrusive structure. The design process takes into consideration the interaction of the whole building structure and its systems. For example, a building that uses extensive daylighting techniques will reduce the amount of heat given off by lighting fixtures, thus allowing a smaller air conditioning system to be used.[30]

Another important aspect of a green building are the life-cycle impacts that take under consideration the short and long term effects of the building materials, maintenance and operation on the environment and its occupants. Effective green buildings are more than a collection of environmentally friendly ideals and the latest technology. In the United States, buildings account for:[31]

- Between 40 and 49% of the total energy use.
- 25% of total water consumption
- 70% of total electricity consumption
- 38% of total carbon dioxide emissions

The design of the green building sets to reduce the resource consumption and knowing the expected impacts to the environment and the occupants can serve to reduce resource demand and enhance the enjoyment of life.

Another important aspect of green building is the use of building materials. This starts with the materials already on site, such as earth and vegetation. The designer needs to consider whether to use low or high impact materials. A low impact material for example is less toxic or carcinogenic. A good example would be choosing insulation made from low VOC (volatile organic compounds) emitting materials. Another example is water based lead free paint. A product may be considered green for more than one reason. Recycled plastic lumber, is an example of multiple reasons for being considered green: it is made from recycled waste, highly durable, and will not need pesticide treatment. On the other hand, wood treated with preservatives may have an advantage in terms of durability, but would represent a health risk for the occupant of the building.[32]

Energy use within a structure is also an important consideration when building green. The types of windows and the positioning of the structure to take advantage of the cooling breeze and sunlight can reduce demands on energy use. In addition, to be considered is the installation of a heat recovery system. Such a system can reduce cooling and heating costs. On-site generation of renewable energy by using solar power, wind power or biomass can significantly reduce energy demands.

Water use is another important consideration in the construction of a green building. Use of on-site wells or the collection of rainwater is used for irrigation. Greywater can also be used. Greywater is the use of wastewater from sources such as dishwashing and washing machines can be used for irrigation or other non-potable purposes.

3.3 Conclusion

Based on the literature review, a green building is one whose structure is designed, built, and operated in such a way that the negative impact to human health and the environment will be reduced. This includes resources used during construction and operation of the building once it is completed. The making of a green building starts with the design. Design of green buildings is critical and considers many components. The Green Building Council and the National Association of Home Builders has developed a rating system that gives a building a number. The higher the number the more a building meets the definition of green. In order to become certified under either rating system a building must utilize materials and building practices as defined by these organizations. The goal of either certification process is to reduce the impact on resources.

4.0 Methodology

4.1 Develop Definition of a Green Building

Running concurrent with the criteria research, a more clear definition of a green building was developed. This involved extracting descriptions from the literature and discussions. These descriptions are compiled into a single chapter. From the descriptions a single definition has been developed. The definition forms the basis from which the comparison between the green office building and single-family home was constructed.

4.2 Identify Criteria Research

Research identified the specific types of green operational practices that are used in the construction of an office building and single-family home. This included the examination of existing practices used by designers and contractors in the development of construction projects. More specifically the goal of this part of the research identified specific processes used that make this type of construction element green. The outcome of this task was the creation of a list with descriptions of each practice used that is considered part of building green. This then formed the baseline criteria used in the creation of the spreadsheet.

4.3 Creation of Spreadsheet

A database spreadsheet was created once the specific operational practices for the development of a green structure had been identified from the previous task. The spreadsheet includes a list of green office and home construction projects and the:

- Identification of the processes that were used that fit the identified criteria.
- Area of the country the project was located.

- Cost for the project where available.
- Any significant issues either positive or negative that may be identified.

This spreadsheet is used during the research stage to compile the data of the actual green projects that have been completed.

4.4 Research

This portion of the thesis researched completed green office building and home construction projects. Using the spreadsheet created in the previous task, a database was then created in which the selected criterion for each project will be logged. In order to complete a comparable set of data, a minimum of twenty-five each of office building and single-family home projects was researched. The number researched may increase or decrease depending on the level of data collected during this process. Each of the basic criterions that have been identified must be answered. Otherwise, the data is unacceptable. Acceptable criterion is:

- The processes that were used that fit the identified criteria as defined in the criteria creation task.
- Area of the country the project was located.
- Cost for the project.

The database forms the basis for the comparison of the office building and the single-family home in the thesis. The database was set up to allow sorting by any of the established criterion. This then allowed for easier evaluation and comparison in the thesis.

5.0 Results

5.1 Definition of a Green Building

There are many definitions of a green building based on the perspective of the individual. Earlier in this thesis a green building was described as one that is designed to reduce or eliminate the impact on human health and the natural environment. This is accomplished by incorporating materials and operational elements that are environmentally responsible and resource efficient throughout the life-cycle of the building.[33] How “Green,” a building can become depends upon the number of the incorporated elements that are used and their associated impact to the human health and the environment.

5.2 Green Elements

This section discusses the components of a green building by taking an in depth look at those elements that make a building green. In order to create commonality in this thesis, the categories developed by LEED for Homes will be used. This was done because LEED for Homes is comprehensive and covers the spectrum of green building aspects. This thesis is not favoring LEED for Homes over any other descriptive or rating system, but merely using the categories as way to approach and discuss the elements that make up a green building.

It is also important to note that going forward the term “category” is used to describe the eight main groupings, while an element is used to describe the components that make up each category. The elements are defined in greater detail within each of the eight categories as defined in LEED for Homes. It is important to understand the components and depth of the “greenness,” of a building in order to be able to begin to draw a comparison between an office building and a single-family home. From the details explored in each category the criteria used in the development of the database will then be derived. The eight categories are: innovation and design, location and linkages, sustainable sites, water efficiency, energy & atmosphere, material & resources, indoor air quality and awareness & education. Each category will start with the basic LEED description including LEED for New Construction as well as the LEED for Homes. This will be followed by a discussion of the elements that fit into each category.

5.2.1 Innovation & Design Process

The basic intent of LEED for Homes is special design methods, unique regional credits, measures not currently addressed in the rating System, and exemplary performance levels. The LEED for Homes lists three ways to earn points for innovation and design. This can be accomplished by promoting an integrated, system-oriented approach to green project design and development. Projects teams are suggested to maximize the development of the green project. Suggested activities for the project team include:

- Conceptual or schematic design;
- LEED planning;
- Preliminary design;
- Energy and envelope systems analysis or design;
- Design development;
- Final design, working drawings or specifications; and
- Construction.

Building orientation for solar design receives points for example if 90% of the glazing on the south-facing wall is completely shaded, the roof has a minimum of 450 square feet of south-facing area that is oriented appropriately for solar applications, the east-west axis is within 15-degrees of due east-west and the glazing area on the north-south facing walls are at least 50% greater than the sum of the east-west walls. The credits are given for durable planning and management, all related to the planning process prior to the start of construction. [34]

LEED for New Construction encourages design and implementation of components that go above the minimum LEED requirements. Under LEED for New Construction extra points are awarded for activity as energy performance or water efficiency, strategies or measures that demonstrate a comprehensive approach and quantifiable environment and/or health benefit.[35]

The United States Department of Energy (USDOE) states that both site selection and planning have a major impact on the relative “greenness” of any facility. The selection includes issues such as transportation and travel distances for building occupants, impacts to wildlife and hydrology (storm water flows, wetlands, etc.). These decisions will impact the immediate natural community as well as the building energy consumption and occupant comfort. Good site planning minimizes site-clearing and preserves existing vegetation. Existing vegetation avoids supplemental irrigation and fertilizer. Mature strands of native vegetation provide energy saving shade and wind control that would otherwise require years to develop from new plantings. Placement of the building on the site promotes energy conservation by taking advantage of natural site features such as topography, sunlight, shade and breezes.[36]

In the site design and planning phase efforts are made to minimize resource costs and site disruption. The USDOE recommends the following guidelines be followed[37]:

- Natural Site Features - Preserve natural drainage systems, locate driveways, parking, entrances, and loading docks on the buildings south side (this is especially important in snowy climates to prevent buildup of snow and ice), orient the building with the long side facing in line with the east-west axis(this allows for the highest winter solar gains and lower summer solar gains), minimize ground-level wind loads (control winds at ground level with the use of vegetation, walls, fencing and natural topography.

- Vegetation – Minimize native vegetation disruption. Locate and size facilities to avoid cutting mature vegetation. Minimize the visual impact by using natural vegetation and adjust the building plan to minimize the visual impacts of facilities.

- Hydrology – Minimize erosion by locating and design the building to minimize impact on erosion and natural hydrological systems. Safeguard hydrological systems from contamination during construction. Allow precipitation to naturally recharge groundwater.

- Soils/Geology – Minimize excavation and disturbance of groundwater. Avoid large impervious surface areas and building footprints that collect rain and create concentrated runoff onto the site.

- Heat Island Effect – Using trees for shade and less pavement reduces or avoids air-conditioning use. Reflective coatings on pavement and roofs will reduce a sites contribution to the heat island effect. Air in urban areas can be 6 – 8 degrees F hotter than surrounding areas and contribute to smog and higher energy use.

The whole building design is defined by the USDOE as the integration of all the building components and systems to determine how they best work together to save energy and reduce environmental impact.

The NAHB's, Lot Design, Preparation, and Development category states that even before the foundation is poured, careful planning can reduce the home's impact on natural features such as vegetation and soil; and enhance the home's long-term performance. Such preparation can provide significant value to the homeowner, the environment, and the community. These reduce environmental impacts and improve energy performance of a new home. For example, saving trees already on-site and constructing onsite storm water retention/infiltration features and orienting houses to maximize passive solar heating and cooling are basic processes used in the design and construction of green homes.[38]

5.2.2 Location & Linkages

The basic intent of LEED for Homes is the placement of homes in socially and environmentally responsible ways in relation to the larger community. There are six areas where points can be earned in this LEED category for Homes:

- Neighborhood development by complying with LEED for Neighborhood Development program,
- Avoid development on environmentally sensitive sites, for example no building at or below a 100-year flood plain, 100 feet of any waterway, on any site that has listed federal or state threatened or endangered species, land that contains "prime soils," "unique soils," or "soils of state significance."
- Encourage building homes near or within existing communities for example build on a previously developed lot.
- Build homes in developments that are served by or are near existing infrastructure. Home must be within at least ½ mile of existing services.
- Build homes that allow for walking, biking, or public transportation, thereby minimizing use of automobiles and their associated environmental impacts.
- Select a site that is within ½ mile of a publically accessible or community-based space at least ¾ acre in size.[39]

LEED for New Construction does not have a rating category specifically for this subject area. However, many of these requirements are found in the Sustainable Sites category which is subdivided into eight separate eligible credits and one requirement. A summary of those credit items pertaining to the Location & Linkages category are:

- Avoid development of inappropriate sites and reduce environmental impacts from the location of the building on a site. The requirement is much the same for New Construction as it is for Homes.
- Channel developments to urban areas with existing infrastructure, protect Greenfield's and preserve habitat and natural resources. Points can be earned for building in specifically named types of urban area (i.e. a bank, day care, community center etc.) and densities (neighborhood with a density of greater than 10 units per acre).
- Rehabilitate Brownfield damaged sites where development is complicated by environmental contamination, reducing pressure on undeveloped land.
- Development of alternative transportation by using public transportation by building no more than ½ mile of existing or planned public transportation, and provide bicycle racks and/or storage at the entrance to the building, use only low-emitting and fuel- efficient vehicles, and parking lot size to meet the minimum local zoning parking requirements.[40]

5.2.3 Sustainable Sites

The basic intent of LEED for Homes is to use the entire property so as to minimize the project's impact on the site. There are six point earning segments within LEED for Homes:

- Site Stewardship – minimize long-term environmental damage to the building lot during the construction process. Accomplish this by pre-planning for the construction to: minimize areas disturbed on the site, erosion protection, and preserve existing plantings.

- Design landscaping features to avoid invasive species and minimize the demand for water and the need for synthetic chemicals, limit the use conventional turf, and use drought resistant plants.
- Design landscaping to reduce the local heat island effect. Accomplish this by placing plantings to provide shading and install light-colored materials over at least 50% of the sidewalks, patios, and driveways within 50 feet of the house.
- Design site features to minimize erosion and runoff from the site. For example; design the lot such that 70% of the build environment (not including the roof area), is permeable to capture water runoff.
- Design the home features to minimize the need for poisons for insects, rodents and other pests. For example: keep all wood (i.e. siding, trim, structure) 12 inches above the soil, seal external cracks, joints, etc., no wood-to-concrete connections, install landscaping so that mature plants are at least 24 inches from the home, and implement termite control measures that meet specific LEED criteria.[41]
- Make use of compact development patterns to conserve land and promote community livability, transportation efficiency, and walkability. Another way to phrase this requirement is to build in areas where homes are already located to minimize impact on unused land.

The basic intent of LEED for New Construction is to reduce pollution from construction activity, avoid development of inappropriate sites and reduce the environmental impacts of the location of the building on the site. LEED for New Construction is similar to LEED for Homes, with a few differences. For example, limit site disturbance to within 40 feet of the building perimeter. Specific to New Construction are:

- Provide a high ratio of open space to the development footprint to promote biodiversity.
- Limit disruption and pollution of natural water flows by managing storm water runoff.
- Minimize light trespass from the building and site, reduce sky-glow to increase access, improve nighttime visibility through glare reduction, and reduce development impact on nocturnal environments.[42]

The USDOE under its recommendation for Site Planning and Land Development states that consideration to the entire community and existing infrastructure in addition to the individual building can amplify the benefits of green home building. For example, by the improvement of a subdivision's storm water management plan and preserving the available natural surroundings through careful design and construction, can impact the entire community and reduce infrastructure costs. [43]

5.2.4 Water Efficiency

The basic intent of LEED for Homes is to provide water-efficient practices, both indoor and outdoor. There are three elements within this category where points can be earned:

- Use of municipal recycled water, or offset central water supply through the capture and controlled reuse of rainwater and /or greywater. Rainwater storage systems must hold all the water from a one-inch rainfall event and/or use a greywater system collecting water from clothes washer, showers and some faucets.

Reduce demand for outdoor water through water-efficient irrigation. For example install moisture sensor controllers.

- Minimize indoor demand for water through water-efficient fixtures and fittings.[44]

The basic intent of LEED for New Construction is to limit or eliminate the use of potable water and use other natural surface or subsurface water resources available on or near the site. There are also three elements in the LEED for New Construction for water use efficiency:

- Limit or eliminate the use of potable water, or other natural surface or subsurface water source available on or near the project site, for landscape irrigation. Requirement is to reduce water use by 50% of the calculated mid-summer baseline. Use only captured rainwater, recycled wastewater or recycled greywater.
- Reduce the generation of wastewater and potable water demand, while increasing the local aquifer recharge by using water-conserving fixtures, or treat 50% of the wastewater on-site to tertiary standards.
- Maximize water efficiency within the building to reduce the burden on municipal water supply and wastewater systems.[45]

The USDOE, in an on-line article, Commercial Building: Site Design and Planning, says, "Water efficiency is the planned management of potable water to prevent waste, overuse, and exploitation of the resource. Effective water-efficiency planning seeks to, do more with less, without sacrificing environmental performance." The USDOE recommends reducing water use for landscaping, and other outdoor demands by using recycled water, or water with greywater.[46]

The NAHB in its recommendation for water conservation measures suggests reducing the impact on natural water resources, storm water and wastewater treatment. Water availability and usage varies from region to region, the concern with adequate supply is becoming widespread geographically. The mean per capita daily indoor water use is slightly over 64 gallons. A green home conserves water indoors and out. Landscaping can reduce outdoor water use and provide energy use reductions for the home. Use of native species that are drought resistant and provide cooling shade can make a significant difference in water demand for a home.[47]

5.2.5 Energy & Atmosphere

The basic intent of LEED for Homes is to provide energy efficiency, particularly in the building envelope and heating and cooling design. There are eleven items for possible credit under the LEED for Homes:

- Meet or exceed the performance for an ENERGY STAR label.
- Design and install insulation to minimize heat transfer and thermal bridging. Must meet or exceed by 5% the requirements as listed in Chapter 4 of the 2004 International Energy Conservation Code.
- Minimize energy consumption caused by uncontrolled air leakage into and out of air conditioned spaces.
- Maximize the energy performance of windows. Windows and doors must meet or exceed the requirements of ENERGY STAR performance.
- Energy consumption due to thermal bridges and/or leaks in the heating and cooling distribution system must be minimized. For example, use at least an R-6 insulation around ducts, limit air leakage to the outside envelope by measured flow rates defined in the LEED Home standard.
- Reduce energy consumption associated with the heating and cooling system by following the ASHRAE handbook and that meet the requirements of the ENERGY STAR for Homes national Builder Option Package.
- Reduce requirements for domestic hot water systems, by improving the efficiency of both hot water system design and the layout of the fixtures in the home. For example, plumbing system must meet specified standards written in the LEED manual and piping insulation must have at least an R-4 value

- Reduce energy consumption of interior and exterior lighting. Lighting must have the ENERGY STAR label, motion senor controls on exterior lighting, and use ENERGY STAR rated lamps in at least 80% of the home.
- Appliances must meet ENERGY STAR requirements and clothes washers receive extra points if modified energy factor is reached.
- Reduce the consumption of nonrenewable energy sources by installing and operating renewable electric generation systems. A calculation formula is supplied with the manual to determine whether this criterion has been met. The LEED manual does not specify the method that the energy comes from.
- Select and test air-conditioning refrigerant to ensure performance and minimize contributions to ozone depletion and global warming.[48]

The basic intent of LEED for New Construction is verifying that the energy related systems are installed and performing according to the project design as well as establishment of maximum energy efficiency, reduce ozone depletion, increase use of renewable energy, provide for ongoing accountability of energy consumption over time and encourage development of renewable energy technologies on a near zero pollution basis. More specifically, there are seven areas where credit can be earned under the LEED for New Construction:

- Verification that the building's energy systems are installed calibrated and performs according to the project requirements, basis of design, and construction documents. LEED allows for the use of a number of verifying agencies that supply signed verification of energy standards.
- Establish the minimum level of energy efficiency for the building and systems by designing the project to comply with mandatory and prescriptive provisions of ASHRAE/IESNA.

- Reduce ozone depletion by zero use of CFC-based refrigerants in the air conditioning systems. Comply with the Montreal Protocol minimizing direct impact on global warming.
- Achieve increased levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use. LEED defines four methods that can be used to achieve this requirement, while not presented here they can be found in the LEED for New Construction Manual, Version 2.2, Energy & Atmosphere section, pages 33 – 35.
- Encourage and recognize increasing levels of on-site renewable energy self-supply in order to reduce environmental and economic impacts associated with fossil fuel energy use. No specific method of energy production is required, but non-polluting sources that are suggested include solar, wind, geothermal, low-impact, biomass and bio-gas. This includes providing at least 35% of the buildings electricity from renewable energy sources.
- In the building design process include additional activities that can be completed and verified that can be added or improved upon.
- Provide ongoing accountability of the building energy consumption over time through the development and implementation of a Measurement & Verification Plan.[49]

The USDOE has a significant focus on energy use. Specifically breaking energy use in commercial buildings into; water heating, appliances and equipment, heating, ventilating, and air conditioning and lighting and daylighting. A brief synopsis of each is supplied here:

- Water Heating – A significant amount of energy can be tied up in water heating. In the lodging industry 42 percent of energy use goes to heat water. The USDOE lists and describes in detail a number of technologies available to reduce energy demands for heating water:[50]

- Conventional water heating efficiency
- Drain water heat recovery
- Heat pump water heating
- Demand (tankless or instantaneous) water systems
- Solar water heating

- Appliances and Equipment – office equipment, food service equipment, and laundry equipment consume energy and present opportunities for energy reduction in commercial buildings. The USDOE estimates that in the United States office equipment accounts for 7 percent of electrical consumption each year. The main focus by the USDOE is the use of ENERGY STAR listed equipment, but also on shutting down equipment when not in use.[51]
- Heating, Ventilating, and Air Conditioning – HVAC systems accounts for 40 to 60 percent of the energy used in the United States for commercial and residential buildings. ASHRAE is the recommended source for HVAC information and technologies. The USDOE recommends looking at alternate sources of energy such as wind power, solar- assisted systems, and cogeneration.[52]
- Lighting and Daylighting – Lighting is essential to any building and provides aesthetics of indoor spaces, and illumination for tasks and activities. An efficient lighting strategy, including natural daylighting, can provide proper levels of illumination and reduce energy costs. Lighting technologies include:[53]
    - Lamps – lighting sources, like fluorescent and incandescent light bulbs, and solid-state lighting.

- Ballasts – used with electric-discharge lamps such as fluorescent lamps, ballasts transform and control electrical power to the light.
- Luminaries (Fixtures) – complete lighting units that contain the bulbs and, if necessary, the ballasts.
- Lighting Controls – devices such as timers and sensors that can save energy by turning lights off when not in use.
- Daylighting – the use of natural light in a building.

Minimizing the environmental impacts of energy used in the construction, operation of the home and in the making of the construction materials. This is the most quantifiable aspect of green building. This helps the builder create a better building envelope and incorporate more energy efficient mechanical systems, appliances, and lighting into the home, yielding long-term utility bill savings and increased comfort for the homeowner.[54]

Energy used to heat and cool a home over its lifetime is significant. However, energy used during the construction phase is also significant, especially when you consider the number of homes built every year (estimated at 1.85 million per year in 2006). NAHB estimates that between 1990 and 2001 the average home consumed about 12,800KWh per year for space and water heating, cooling, and lights and appliances. Total energy expenditures during a year cost the homeowner about $1,600. Energy efficiency improvements in a green home can reduce that cost by at least 20%. In regards to the guidelines, the most significant improvements are from a “whole systems” approach to the building of a green home.[55]

5.2.6 Material & Resources

The basic intent of LEED for Homes is efficient utilization of materials, selection of environmentally preferable materials, and minimization of waste during construction. LEED for Homes has three areas in which points can be earned:

- Optimize the use of framing materials by limiting the overall waste factor to 10% or less. LEED defines waste factor as the percentage of framing material ordered in excess of the estimated material needed for construction. Credits are given for detailed advance planning for lumber requirements for the frame.
- Use products that are extracted, processed, and manufactured within the region. Provide all wood products that meet specified LEED environmentally preferred product requirements as defined in the LEED manual. In order to receive credits the materials must make up 90% of the component (i.e. environmentally preferable, low emissions, and local sourcing) by weight or volume. This applies to either a combination of components or single components. Use products that meet specifications as defined by LEED for low emissions, and/or are of local production and were extracted, processed, and manufactured within 500 miles of the home.
- Reduce waste generation to a level below the industry norm. Investigate, document and recycle all project waste stream materials. Industry norm is defined by LEED as the generation of 2.5 pounds of waste or less per square foot of conditioned floor area. The LEED for Homes manual contains a calculation formula for determining this.[56]

The basic intent of LEED for New Construction is the storage and collection of recyclables by the occupant and divert construction waste material from landfill disposal. Also facilitate the use of existing building materials, use of local and recycled (pre and post consumer) materials, reduce the use of raw materials in the construction of the building. LEED for New Construction has one prerequisite and seven optional requirements for credit. LEED requires that easily accessible area be provided that serves the entire building, providing collection services for glass, plastic, office paper, newspaper, cardboard and organic wastes. The seven optional items consists of:

- Extend the life-cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport. Maintain at least 75% (based on surface area) of existing building structure (including structural floor and roof decking) and envelope (exterior skin and framing, excluding window assemblies and non-structural roofing material).
- Divert construction, demolition and land-clearing debris from disposal in landfills and incinerators. Redirect recyclable recovered resources back to the manufacturing process. Redirect reusable materials to appropriate sites. Accomplish this by recycling/or salvaging at least 50% on non-hazardous construction and demolition debris.
- Use salvaged, refurbished or reused materials such that the sum of these materials constitutes at least 5%, based on cost, of the total value of materials on the project.
- Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the pre-consumer content constitutes at least 10% (base on cost) of the total value of the materials in the project.
- Use building products that have been extracted, harvested or recovered, as well as manufactured within 500 miles of the project site for a minimum of 10% of the total material value.
- Use rapidly renewable building materials and products (made from plants that are typically harvested within a ten-year cycle or shorter) for 2.5% of the total of all building materials and products used in the project based on cost.
- Use a minimum of 50% of wood-based materials and products, which are certified in accordance with the Forest Stewardship Council's Principles and Criteria, for wood

building components. For example, include, structural framing, flooring, sub-flooring, wood doors and finishes.[57]

The USDOE defines a building envelope as a critical component of any facility as it protects the occupants and plays a major role in regulating the indoor environment. Although referring to the building envelope, the importance to the USDOE is design and material selection as they relate to energy efficiency.

Resource efficiency is also about reducing job-site waste. A construction waste management plan will reduce the amount of material needed for the job and prevent left over material from becoming landfill material. NAHB, in 2003 estimated that the average 2,320 ft^2 single family home in the United States generated between 6,960 and 12,064 lbs. of construction waste. NAHB estimates that creating effective construction management techniques can reduce this waste by at least two-thirds, creating cost savings and reducing the burden on landfill space.[58]

5.2.7 Indoor Environmental Quality

The basic intent of LEED for Homes is improvement of indoor air quality by reducing the creation of and exposure to pollutants. There are ten areas where points can be earned in the LEED for Homes rating system:

- Install an ENERGY STAR approved bundle of air quality measures. This can be accomplished by completing all the requirements of the U.S. Environmental Protection Agency's ENERGY STAR with Indoor Air Package.
- Minimize leakage of combustible gases into the occupied space of the home. Minimum measures are defined in the manual such as no unvented combustion appliances, and a carbon monoxide detector must be installed on each floor.

- Control indoor moisture levels to provide comfort, reduce the risk of mold, and increase the durability of the home. Install dehumidification equipment to maintain humidity at or below 60%.
- Reduce occupant exposure to indoor pollutants by venting with outside air. Install whole building ventilation systems that meet the requirements as established in ASHRAE.
- Reduce moisture and exposure to indoor pollutants in kitchens and bathrooms by meeting specific design requirements such as install exhaust systems with automatic sensors.
- Provide appropriate distribution of space heating and cooling in the home to improve thermal comfort and energy performance.
- Reduce particulate matter from the air supply system by installing air filters.
- Reduce occupants' and construction workers' exposure to indoor airborne contaminants though source control and removal. During construction indoor air contaminants can be controlled by sealing ducts and vents. Install central vacuum system with exhaust to the outdoors and flush the home with fresh air following established LEED guidelines.
- If the home is in EPA Radon Zone 1, build the home with radon-resistant construction as prescribed by the EPA. If outside EPA Radon Zone 1 LEED recommends that radon-resistant construction still be done.
- Reduce exposure to indoor pollutants that originate from an adjacent garage by installing an exhaust fan in the garage, seal shared surfaces between the garage and home to prevent penetration of gases.[59]

The basic intent of LEED for New Construction is establishment of indoor air quality performance as it pertains to the comfort and well-being of the occupants from any hazardous particles or chemical pollutants or biological impacts. Provide lighting, heating and cooling comfort for the occupants. LEED for New Construction has two prerequisites, one that requires ventilation systems that meet ASHAE standards. The other prerequisite requires the minimization of exposure to tobacco smoke. There are eight areas where points can be earned under the LEED for Construction guidelines:

- Install permanent monitoring systems to provide feedback on the performance of the ventilation system Configure system to generate an alarm when conditions vary by 10% of the set point.
- Increase breathing zone ventilation rates to all occupied spaces by at least 30% above the minimum rates as required by ASHRAE.
- Develop and implement an Indoor Air Quality Program for the pre-construction and pre-occupancy phase.
- All adhesives and sealants used on the interior of the building shall comply with the requirements by the standards as referenced in the LEED for New Construction manual. This requirement is in reference to the VOC content of materials.
- Design to minimize and control pollutant entry into the building and later cross-contamination of regularly occupied areas.
- Provide a high-level lighting system control by individual occupants (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants. This should include providing individual comfort control for at least 50% of the buildings occupants.

- Provide a comfortable thermal environment that supports the productivity and well-being of the building occupants. Also provide for the assessment of the building thermal comfort over time.
- Provide the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building. [60]

The guiding principle from the NAHB defines indoor environmental quality as the creation of healthy and safe indoor air as important in a green building. Indoor air quality is often cited as the second most important feature of a green home after energy use. More attention is being paid the type of building material used and the potential impact they have to the occupants of the home.[61]

5.2.8 Awareness & Education

The basic intent of awareness and education is to provide education of homeowners, tenants, and/or building occupants. The basic requirement of this category is to maintain the performance of the home by educating the occupants about the operations and maintenance of the home's features and equipment.[62] There are no requirements under LEED for New Construction pertaining to awareness and education.

The NAHB stresses education as an important guiding principle. The NAHB says that improper maintenance can defeat the efforts to create a resource efficient home. An example of improper maintenance would be a home owner may fail to change air filters regularly or not operate kitchen or bathroom exhaust air to remove excess moist air. These impacts the air quality of the home and excess moisture can create mold that can impact the health of the occupants. An education program that provides information to the homeowner on how to maintain and operate a green home is provided. A manual on how to optimally operate and maintain the house is provided to the homeowner.[63]

5.3 Database

In order to develop a set of criteria to use in the database the LEED categories for New Construction and Home rating have been combined and are used as the basis for the development of the spreadsheet in which data from identified green homes and office have been entered. The completed database can be found in Appendix A, B and C. The first part of the data lists the corresponding site number unique for that location, each of the building types, (home or office), and other data such as: location, owner, rating type (LEED only and level achieved, if available), square foot of the structure, date completed, cost, architect, general contractor and identification number for the source of the information. The results can be found in Appendix A.

The second part of the data that has been collected is placed in the Detailed Elements Description Section located in Appendix B. This portion of the database is identified by site number (from the List of Structures – Appendix A) and details found for each of eight elements that are used to describe the green aspects of the structure. The elements used are the same as those of LEED for Homes. As described in the last section, this was done to create commonality and make it easier to log in the data and does not support LEED over any other system used for measuring or identifying green. The eight elements used in the database and brief summary description of each are:

- Innovation & Design Process –Special design methods or unique reasons for adding green to this construction project and/or something that stands out from most other similar type of construction activity. Innovation and design starts with the planning and there can creative ways to achieve green.

- Location & Linkages – The placement of homes in socially and environmentally responsible ways in relation to the larger community. Are there historic, economic, or even community related reasons for locating at a specific site? Location to public transportation, revitalizing contaminated sites or building on sites that contain or did contain structures.
- Sustainable Sites – The use of the entire property so as to minimize the project's impact on the site. Building on a site utilizing existing natural resources, or using resources that require less material.
- Water Efficiency – Water-efficient practices, both indoor and outdoor. Even eliminate water use in certain situations.
- Energy & Atmosphere – Energy efficiency, particularly in the building envelope and heating and cooling design. Use of alternate sources of energy such as wind, solar or, thermal energy sources.
- Material & Resources – Efficient utilization of materials, selection of environmentally preferable materials, and minimization of waste during construction. Use of recycled materials or materials with recycled content.
- Indoor Environmental Quality – Improvement of indoor air quality by reducing the creation of and exposure to pollutants. Indoor comfort in regards to temperature, noise or light is important environmental quality related concerns.
- Awareness & Education - The education of homeowners, tenant, and/or building manager about the operation and maintenance of the green features. Is the awareness and education plan extended beyond the occupants of the building to include visitors?

These eight elements form the basis for the comparison for this thesis. Appendix C contains the list of references from where the research data was collected.

5.4 Research – Complete Projects

This element researched completed green office building and home construction projects. The data is recorded in the database as described in the previous section. The original research methodology was to collect data a minimum of twenty-five each of office building and single-family home projects. The actual research yielded a total of 30 projects consisting of fourteen office and sixteen home construction projects. Every effort was made to search for projects at random, with enough available detail, scope and size. Another important aspect was to select sites from various areas of the United States. The recorded data can be found in Appendix A and B. The selected projects fit the acceptable criterion as defined in the methodology.

6.0 Analysis and Discussion

This chapter covers a discussion and analysis of the research conducted for a green single-family home and an office building. From the research a definition of green is discussed. This is followed by a discussion of the eight elements of a green building as they pertain to a single-family home and an office building. The results obtained from the data collected on thirty completed projects are used to discuss and then compare the eight elements that make up a green building.

Making use of the natural resources of a site and the materials available at or near a site is an important step in becoming green. Green includes designing a structure, site use, and the minimal consumption of resources once the building is occupied. Sustainability in terms of construction also considers impact on community. One of the better definitions of green has been written by The California Integrated Waste Management Board and forms the basis for this thesis. The California Integrated Waste Management Board defines a green building as, "A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment."[64] The concept of green can then be said to be based on how "green" is a building or the "greenness." How far does the builder want to take green and make the structure sustainable?

6.1 Discussion of The Eight Elements

The eight elements taken from LEED for Homes form the discussion of the research results in this thesis. No specific type of green single-family home or office building was selected for the research. Nor was the location of importance except to select from a number of different locations throughout the Country, which provided a variety of differing climates. Variety was more important as it was felt that a cross section of building types in terms of location, cost, and climate would yield wider results and result in a more general view of what is actually occurring in the real world. It is also important to note that there was no requirement that the structures had to be LEED rated; as a matter of fact many are not.

Tables are provided for each of the elements that are discussed to show those structures that met each element within the LEED category. A total of the number of homes and office building for each of the elements within the category is provided. This is used to provide a comparison between a home and an office building.

6.1.1 Innovation & Design Process

Innovation and Design Process is defined as special design methods or unique reasons for adding green to a construction project. What within the project stands out from most other similar type of construction activity? Innovation and design starts with the planning and include creative ways to achieve green. There are a number of innovative designs used that allow a structure to become more efficient in resource use and conservation of energy. Table 6.1 lists those sites that exhibit unique design.

There are nineteen sites (63% of the 30 sites) exhibiting characteristics for at least one of the nine elements within innovation and design. Roof design, three each for home and office building were included more than any other element in the construction. Other elements with higher ranking include unique air moving systems and use of on-site materials. Based on the data there are fourteen (61%) elements exhibited by office building verses nine (39%) for the single family home.

Table 6.1
Innovation and design

ID Number	Building Type	Location	Cooling w/vegetation	Roof design	Wetland for cooling	Unique air moving systems	Use of on-site materials	Location for solar use	Geothermal system	Heat reflecting material in construction	Universal design
10	Home	Rockland, Calif.									
11	Home	Freeport, Maine		X				X			
13	Home	San Diego, Calif.					X				
14	Home	Gainesville, Fla.								X	
20	Home	Kerhonkson, N.Y.							X		
22	Home	Chicago, Ill.		X							
24	Home	Glenville, N.Y.									X
28	Home	Venice, Calif.		X				X			
8		**Total Home**		**3**			**1**	**2**	**1**	**1**	**1**
1	Office	Washington, D.C.				X					
2	Office	Providence, R.I.	X	X			X				
3	Office	Overland, Missouri									
4	Office	Little Rock, Arkansas		X							
5	Office	Little Rock, Arkansas			X	X					
6	Office	Portland, Oregon		X		X					
7	Office	Stanford, Calif.				X					
8	Office	Berkeley, Calif.					X				
9	Office	Boise, Idaho							X		
26	Office	Denver, Colorado						X			
29	Office	Chelmsford, Mass.					X				
11		**Total Office**	**1**	**3**	**1**	**4**	**3**	**1**	**1**		
19		**TOTAL OVERALL**	**1**	**6**	**1**	**4**	**4**	**3**	**2**	**1**	**1**

6.1.2 Location & Linkages

The location and linkages element is defined as the placement of homes in socially and environmentally responsible ways in relation to the larger community. There are historic, economic, or even community related reasons for locating at a specific site. Location of the project in relation to public transportation, revitalizing contaminated sites or building on sites that contain or did contain structures is another part of this element. Table 6.2 lists the sites with the applicable impacted element.

There are twenty-one sites (70% of the 30 sites) exhibiting characteristics for at least one of the five elements within the location category. Six homes and four offices for a total of ten, exhibited the element of siting of building in the construction. Other elements with a higher ranking include location near public transportation (a total of seven) and built on pre-existing sites (a total of six). Based on the data there are eleven (41%) elements exhibited by office building verses sixteen (59%) for the single family home.

Table 6.2
Location

ID Number	Building Type	Location	Located near public transportation	Siting of building	Built on pre-existing site	Public use buildings nearby	Preserves local history
10	Home	Rockland, Calif.	X			X	
13	Home	San Diego, Calif.					X
14	Home	Gainesville, Fla.		X			
16	Home	Boulder, Colorado	X		X		
19	Home	Boulder, Colorado			X		
20	Home	Kerhonkson, N.Y.		X			
21	Home	Evanston, Ill.		X			
22	Home	Chicago, Ill.	X	X	X	X	
24	Home	Glenville, N.Y.		X			
27	Home	Tukwila, Wash.	X				
28	Home	Venice, Calif.		X			
11		**Total Home**	**4**	**6**	**3**	**2**	**1**
1	Office	Washington, D.C.		X			
2	Office	Providence, R.I.		X			
3	Office	Overland, Missouri		X			
5	Office	Little Rock, Arkansas			X		
6	Office	Portland, Oregon	X				
9	Office	Boise, Idaho	X			X	
25	Office	Washington, D.C.			X		
26	Office	Denver, Colorado	X				
29	Office	Chelmsford, Mass.		X			
30	Office	Arlington, Va.			X		
10		**Total Office**	**3**	**4**	**3**	**1**	
21		**TOTAL OVERALL**	**7**	**10**	**6**	**3**	**1**

6.1.3 Sustainable Sites

The definition of a sustainable site is the use of the entire property so as to minimize the project's impact on the site and utilizing existing natural resources, or using resources that require less material. Many of the sites use native plants in their landscaping scheme thereby reducing water demands and labor needed for maintenance. Another reported use of some of the sites is the material located on the site itself for construction. Recycling of construction waste, ranging from 62% to 85% was utilized at many of the sites that were examined. This prevents waste from ending up in landfills. Table 6.3 lists the sites with sustainable aspects.

There are twenty-five sites (83% of the 30 sites) exhibiting characteristics for at least one of the eight elements within the location category. Use of native plantings, a total of twelve or eight for homes and four for office exhibited this element in the construction. Other elements with higher ranking include use of on-site building materials (a total of six) and 70% or more of construction materials were recycled (a total of five). Based on the data there are sixteen each of the elements exhibited by the home and office building.

Table 6.3
Sustainable

ID Number	Building Type	Location	reduced heat island effect	Partial or full green roof	Collects more rainwater than can be used	Native plantings	On-site building materials	70% or more construction waste recycled	Near public transportation	On-site geothermal system
10	Home	Rockland, Calif.						X		
11	Home	Freeport, Maine				X	X			
12	Home	Westwego, Louisiana								
13	Home	San Diego, Calif.				X	X			
14	Home	Gainesville, Fla.				X		X		
18	Home	Charleston, R.I.				X	X			
19	Home	Boulder, Colorado				X				
20	Home	Kerhonkson, N.Y.								X
21	Home	Evanston, Ill.					X			
23	Home	Santa Monica, Calif.				X				
24	Home	Glenville, N.Y.				X				
27	Home	Tukwila, Wash.				X				
28	Home	Venice, Calif.					X			
13		**Total Home**				**8**	**5**	**2**		**1**
1	Office	Washington, D.C.	X	X						
2	Office	Providence, R.I.		X						
4	Office	Little Rock, Arkansas			X					
5	Office	Little Rock, Arkansas				X				
6	Office	Portland, Oregon		X					X	
7	Office	Stanford, Calif.				X				
8	Office	Berkeley, Calif.				X		X		
9	Office	Boise, Idaho							X	X
25	Office	Washington, D.C.						X		
26	Office	Denver, Colorado						X		
29	Office	Chelmsford, Mass.				X	X			
12		**Total Office**	**1**	**3**	**1**	**4**	**1**	**3**	**2**	**1**
25		**TOTAL OVERALL**	**1**	**3**	**1**	**12**	**6**	**5**	**2**	**2**

6.1.4 Water Efficiency

The water-efficient element includes the reduction of water use and elimination for water sources outside the site itself. Table 6.1.4 shows the major water saving elements from the sites examined. The control of water runoff from storm water is also an important aspect of this element. Water use and the reduction therein was an important consideration for most of the sites examined. The use of waterless urinals, and low flow faucets were very common among the sites examined. Use of captured water for irrigation was utilized on a number of the projects. A number of sites utilize water collection systems for various uses ranging from irrigation, heating system use and cooling.

There are twenty-two sites (73% of the 30 sites) exhibiting characteristics for at least one of the nine elements within the water efficiency category. Fourteen sites used some form of rainwater collection system; five of the home and nine of the office buildings were included more than any other element in the construction. Other elements with higher ranking include use of native plants and a green roof. Based on the data there are thirty-one (66%) elements exhibited by office building verses sixteen (34%) for the single family home.

Table 6.4
Water Efficiency

ID Number	Building Type	Location	Collect rainwater	Retention Ponds	Greywater used	Bioreactor	Closed loop heat system	Green roof	Waterless urinals	Use native plants	Water efficient fixtures
11	Home	Freeport, Maine								X	
12	Home	Westwego, Louisiana									
13	Home	San Diego, Calif.					X			X	
14	Home	Gainesville, Fla.	X				X			X	
18	Home	Charleston, R.I.	X							X	
19	Home	Boulder, Colorado								X	
22	Home	Chicago, Ill.	X					X			
23	Home	Santa Monica, Calif.	X					X		X	
24	Home	Glenville, N.Y.	X							X	
27	Home	Tukwila, Wash.	X							X	
10		**Total Home**	**5**				**2**	**2**		**7**	
1	Office	Washington, D.C.	X					X	X		X
2	Office	Providence, R.I.	X						X	X	
3	Office	Overland, Missouri	X	X					X	X	
4	Office	Little Rock, Arkansas	X								
5	Office	Little Rock, Arkansas	X		X				X		
6	Office	Portland, Oregon	X			X		X			
7	Office	Stanford, Calif.						X			
8	Office	Berkeley, Calif.							X		X
9	Office	Boise, Idaho	X		X						
25	Office	Washington, D.C.									X
26	Office	Denver, Colorado	X					X			X
29	Office	Chelmsford, Mass.								X	X
12		**Total Office**	**9**	**1**	**2**	**1**		**4**	**5**	**4**	**5**
22		**TOTAL OVERALL**	**14**	**1**	**2**	**1**	**2**	**6**	**5**	**11**	**5**

6.1.5 Energy & Atmosphere

Energy and atmosphere element concerns the energy efficiency, particularly in the building envelope and heating and cooling design. Table 6.5 shows the sites with elements within the energy and atmosphere category exhibiting criteria. Also, the uses of alternate sources of energy such as wind, solar or, thermal energy sources are important aspects of energy. Energy is an important focus at each of the sites in the research. Many of the designs used solar power and heating as a major component of the energy plan.

There are twenty-eight sites (93% of the 30 sites) exhibiting characteristics for at least one of the eight elements within the energy and atmosphere category. Solar power, nine each of the homes and five of the office buildings were included more than any other element in the construction. Other elements with higher ranking include energy savings appliances and devices as well as the use of air flow systems for cooling. Based on the data there are twenty-four (52%) elements exhibited by office building verses twenty-two (48%) for the single family home.

Table 6.5
Energy and Atmosphere

ID Number	Building Type	Location	Green roof	Solar Power	Wind Power	Geothermal heat source	Air flow systems for cooling	Energy saving appliances and devices	Non-CFC cooling devices	Shade providing techniques
10	Home	Rockland, Calif.		X						
11	Home	Freeport, Maine		X						
12	Home	Westwego, Louisiana						X		
13	Home	San Diego, Calif.		X						
14	Home	Gainesville, Fla.					X	X		
15	Home	Boulder, Colorado		X						
18	Home	Charleston, R.I.		X						X
19	Home	Boulder, Colorado						X		
20	Home	Kerhonkson, N.Y.				X				
21	Home	Evanston, Ill.		X						
22	Home	Chicago, Ill.	X				X			
23	Home	Santa Monica, Calif.	X	X			X			
24	Home	Glenville, N.Y.						X		
27	Home	Tukwila, Wash.		X				X		
28	Home	Venice, Calif.		X						X
15		**Total Home**	**2**	**9**		**1**	**3**	**5**		**2**
1	Office	Washington, D.C.						X		
2	Office	Providence, R.I.	X	X					X	
3	Office	Overland, Missouri		X	X			X		
4	Office	Little Rock, Arkansas					X			X
5	Office	Little Rock, Arkansas					X			
6	Office	Portland, Oregon		X			X			
7	Office	Stanford, Calif.					X			
8	Office	Berkeley, Calif.						X		
9	Office	Boise, Idaho				X	X			
25	Office	Washington, D.C.						X		
26	Office	Denver, Colorado	X	X			X			X
29	Office	Chelmsford, Mass.		X				X		
30	Office	Arlington, Va.						X		
13		**Total Office**	**2**	**5**	**1**	**1**	**6**	**6**	**1**	**2**

6.1.6 Material & Resources

Materials and resources are the efficient utilization of materials, selection of environmentally preferable materials, and minimization of waste during construction. Also the use of recycled materials or materials with recycled content is an important aspect of this element. A Little Rock, Arkansas building (Appendix A and B Site Number 5), built on a site where there was already a building. The building was taken down and most of the materials were reused in the construction of the new building. The new structure was built with 97% of the materials coming from former buildings both on-site or nearby. Many sites complied with the LEED requirement that materials be purchased from local sources within 500 miles even non-LEED rated sites. The use of FSC certified wood products and bamboo for flooring was common. Another important aspect of this element that is commonly used is low impact materials for example low or no VOC's. Many of the building materials themselves are made from recycled components, for example concrete made using fly-ash, and gypsum board made from recycled materials used as insulation. Table 6.6 lists the sites and those with applicable material and resource issues.

There are twenty-five sites (83% of the 30 sites) exhibiting characteristics for at least one of the nine elements within materials and resources category. Low impact materials, six each for homes and eight for office buildings were included more than any other element in the construction. Other elements with higher ranking include use of materials made from recycled materials and FSC certified wood. Based on the data there are seventeen (49%) elements exhibited by office buildings verses eighteen (51%) for the single family home.

Table 6.6
Materials and Resources

ID Number	Building Type	Location	Use of materials made from recycled materials	Cellulose insulation	Low impact materials	FSC certified wood	Concrete insulated forms
10	Home	Rockland, Calif.			X		
12	Home	Westwego, Louisiana	X				
14	Home	Gainesville, Fla.		X	X		
15	Home	Boulder, Colorado		X	X		
16	Home	Boulder, Colorado	X				
18	Home	Charleston, R.I.				X	
19	Home	Boulder, Colorado	X		X		
21	Home	Evanston, Ill.				X	
22	Home	Chicago, Ill.	X		X		
24	Home	Glenville, N.Y.	X				X
27	Home	Tukwila, Wash.			X	X	
28	Home	Venice, Calif.	X				
12		**Total Home**	**6**	**2**	**6**	**3**	**1**
1	Office	Washington, D.C.	X				
2	Office	Providence, R.I.		X	X		
4	Office	Little Rock, Arkansas	X				
5	Office	Little Rock, Arkansas	X				
7	Office	Stanford, Calif.	X		X		
8	Office	Berkeley, Calif.			X	X	
9	Office	Boise, Idaho			X		
17	Office	Boulder, Colorado			X		
25	Office	Washington, D.C.	X		X		
29	Office	Chelmsford, Mass.	X		X		
30	Office	Arlington, Va.			X	X	
13		**Total Office**	**6**	**1**	**8**	**2**	
25		**TOTAL OVERALL**	**12**	**3**	**14**	**5**	**1**

6.1.7 Indoor Environmental Quality

This element as shown in Table 6.7, involves the improvement of indoor air quality by reducing the creation of and exposure to pollutants. Indoor comfort such as temperature, noise or light is an important environmental quality related concerns. Indoor environmental quality aspects within this element include interior lighting provided through skylights and windows, control of the lighting through shades and manual and automatic controls. Other environmental quality aspects include interior temperature comfort, fresh air provided from outside the building, ability to control individual office temperatures and use of low emitting materials such as VOC's.

There are twenty-four sites (80% of the 30 sites) exhibiting characteristics for at least one of the six elements within the indoor environmental quality category. Daylighting, ten each for home and office building were included more than any other element in the construction. Other elements with higher ranking include outside air control system, shading and interior lighting control. Based on the data there are twenty-two (61%) elements exhibited by office building verses fourteen (39%) for the single family home.

Table 6.7
Indoor Environmental Quality

ID Number	Building Type	Location	Shading	Noise controls	Daylighting	Interior lighting control	Outside air control system	Radon evacuation system
10	Home	Rockland, Calif.					X	
11	Home	Freeport, Maine			X			
15	Home	Boulder, Colorado			X			
18	Home	Charleston, R.I.			X		X	X
19	Home	Boulder, Colorado			X			
21	Home	Evanston, Ill.			X			
22	Home	Chicago, Ill.			X			
23	Home	Santa Monica, Calif.			X			
24	Home	Glenville, N.Y.			X			X
27	Home	Tukwila, Wash.			X			
28	Home	Venice, Calif.			X			
11		**Total Home**			**10**		**2**	**2**
1	Office	Washington, D.C.	X			X		
2	Office	Providence, R.I.			X			
3	Office	Overland, Missouri			X			
4	Office	Little Rock, Arkansas			X			
5	Office	Little Rock, Arkansas	X		X	X		
6	Office	Portland, Oregon	X		X	X		
7	Office	Stanford, Calif.			X			
8	Office	Berkeley, Calif.			X		X	
9	Office	Boise, Idaho					X	
25	Office	Washington, D.C.		X	X			
26	Office	Denver, Colorado			X		X	
29	Office	Chelmsford, Mass.			X		X	
30	Office	Arlington, Va.					X	
13		**Total Office**	**3**	**1**	**10**	**3**	**5**	
24		**TOTAL OVERALL**	**3**	**1**	**20**	**3**	**7**	**2**

6.1.8 Awareness & Education

Awareness and education provides information to the homeowners, tenant, and/or building manager about the operation and maintenance of the green features of the building. Of the thirty sites described in the research data, only two office building projects, see Table 6.8, indicated the implementation of a program for awareness and education: the Boise, Idaho (Appendix A and B Site Number 9) has a knowledge wall inside the building and the Arlington, Virginia building (Appendix A and B Site Number 30) a user education program in which signs are placed throughout the building to provide information to the building users and visitors.

Table 6.8
Awareness and Education

ID Number	Building Type	Location	Education Program
9	Office	Boise, ID	X
30	Office	Arlington, Va.	X
2		**Total Office**	**2**

6.2 Comparison

As previously discussed the NAHB has developed a rating certification program separate from the USGBC LEED process. LEED has a separate rating system for a number of different programs including construction and homes that is the discussion of this thesis. Table 6.9 shows the program element comparison between NAHB and LEED for construction and homes. There is little difference between the three rating systems, the elements of which are discussed in chapter 3.2. The LEED Homes and the NAHB both have an education element that isn't emphasized in the LEED for construction.

Table 6.9
Program Element Comparison

LEED Construction	LEED Homes	National Assiciation of Home Builders
Sustainable Site	Sustainable Sites	Lot Design, Preparation, and Development
Energy and Atmosphere	Energy and Atmosphere	Energy Efficiency
Water Efficiency	Water Efficiency	Water Efficiency
Material and Resources	Material and Resources	Resource Efficiency
Indoor Environmental Quality	Indoor Environmental Quality	Indoor Environmental Quality
Innovation and Design	Innovation and Design	Site Planning and Land Development
	Awareness & Education	Operation, Maintenance and Homeowner Education
	Location and Linkages	Global Impact

Table 6.10
Summary of Data

CATEGORY	Innovation/Design	Location	Sustainable	Water	Energy/Atmosphere	Material/Resources	Indoor Environmental Quality	Awareness/Education
Total # of aspects within category	9	5	8	9	8	5	6	1
Total Sites with aspects in this category	19	21	25	22	28	25	24	2
Home	8	11	13	10	15	12	11	0
Office	11	10	12	12	13	13	13	2
Total # of aspects of the sites that met this category	23	27	32	47	46	35	36	2
Home	9	16	16	16	22	18	14	0
Office	14	11	16	31	24	17	22	2

There were sixteen homes and fourteen office projects that were included in the collected data. Table 6.10 lists the numerical totals from Tables 6.1 thru 6.8. Office buildings raked higher than homes five out of the eight categories in the number of times an element was applied. Somewhat of a surprise is that homes scored higher than office buildings in location and material resources. Sustainability was even between the two types of construction.

The research data indicates mixed results regarding project cost; this includes overall building cost or individual portions of the building. This is even truer of the single family home than of the office building. Of the cost information provided (Appendix A) nineteen project sites provided the cost of the building project. Twelve of the fourteen office building projects provided a cost. The cost for the office buildings ranged from $4 million to $160 million and ranged in size from 10,890 square feet to 262,000 square feet. Seven of the sixteen single family homes researched provided costs. These ranged from a 4,450 square foot home for $190,000 to a 2,250 square foot home for $650,000.

Fifteen of the thirty projects researched were LEED rated projects ranging from certified to platinum. Although some of the other sites did receive a rating of one type or another, those ratings were not provided in the research data. A rating was not required as part of the research but merely provided as a reference, especially since the basis of the elements used came from the LEED for Homes rating program.

In comparing the green single-family home with the office building there are similarities and differences between them. The innovation in the design for both types of construction had a range of the status quo to true innovation. The question has to be what is being done differently? In the office building design and construction the more impressive design effort has to be that of the staircase and wetland design used at the Heifer International Center in Little Rock, Arkansas

(Appendix A and B Site Number 5). This design uses available clay soil located on site to create a base for a wetland. The wetland is used to collect storm water and staircases used next to the wetland to circulate warm air up and out of the building. The air passes over the wetland and is cooled before entering the building. Home construction has been creative in design as well. For example, a home in Boulder, Colorado (Appendix A and B Site Number 15) added a 700 square foot addition and the remainder of the home was designed for green, for a total of 1,700 square feet. The home is connected to the power grid but only to sell power back to the utility. There are a number of other design features that made individual buildings unique. For example, the collection and reuse of storm water was a significant issue with most of the sites examined. Water use and its availability can be a premium in many areas of the country.

Of the elements and sites examined water use and energy were by far the most significant issues for designers and owners. Management of water use can be a significant savings to the building user resulting in a positive impact on the environment. The office buildings in the research have some significant water capturing plans and reuse. For example, the Wincock International building in Little Rock, Arkansas (Appendix A and B Site Number 4), where water is collected in a cistern located under the building. Excess water that cannot be held in the cistern is collected in a nearby underground reservoir. The water is used for irrigation with excess water also used by a nearby marina. Another example of water collection and reuse is a Boise, Idaho (Appendix A and B Site Number 9) building that collects water from on-site and nearby streets and parking lots. The water is used for irrigation and along with greywater from the building is used to flush toilets. Water capture and reuse plans were more developed by the office projects than the single-family home. There are examples of significant water capture and reuse by single-family homes as well, for example, the Charleston, Rhode Island home (Appendix A and B Site Number 19), capture and reuse of water for irrigation. Green roofs were also used by both office buildings and single family homes. The roofs absorb rainwater and heat, keeping the structures naturally cooler.

A significant green element in both the office building and single family home is energy use. Production of on-site electricity using solar cells and wind turbines, the use of air flow, green roof and water for cooling, insulation, and ENERGY STAIR appliances are methods used to reduce energy costs. Energy reductions also are important in terms of where buildings are constructed in relation to public transportation. In comparing the energy element of the single family home to the office building there seems to be very similar use of technology. For example solar heating and photovoltaic cells are used in a number of instances for both the single family home and the office building. Eight of the sixteen single family homes and six of the fourteen office buildings use solar power. Offices in Overland, Missouri, (Appendix A and B Site Number 3), and Boulder, Colorado, (Appendix A and B Site Number 17), also use wind turbines to produce electricity. There were no single family homes using wind turbines to produce electricity.

7.0 Conclusions

This thesis intended to include a review the elements that make a building green and complete a survey of building structures. The survey included thirty buildings both office and single-family. The structures were chosen at random that were advertised as being green. The limitation of the research was that only a relatively small sample was taken. The limitation of a small sample did not allow for a broad enough range of data. A larger sample would have been more difficult to manage. An interesting approach in a future project would be to examine each element and the associated impact of the green movement in America.

The research for this thesis started by looking for a universal definition of “green” instead the conclusion is there are many definitions. Green is really about the construction and operation of a building to be ecology friendly. Ecology friendly or a better way to describe green is sustainable in an environmentally responsible way so as to reduce or eliminate the need for resources. Those resources can man-made or natural and are finite in terms of availability is concerned. Green is more than using resources wisely, but also reducing pollution such as CO2 or VOC’s. Carbon foot printing goes beyond the construction and operation of a building. It includes the energy needed to make products used in construction, electricity that is consumed and fuel for vehicles. Green in a broader sense is about protecting future generations by making sure that the resources needed are available.

Another interesting point from the thesis research is the rating systems that are available. As described many times LEED is the most well known, but a number of other agencies the National Association of Home Builders, EarthCraft House and many cities have rating systems. It seems that the rating systems are themselves over rated and tend to be politically motivated. Politics needs to be removed from the greening process. In the site research for the data base a number of the builders decided not to try to achieve a LEED rating because it is a costly process.

There is an increasing trend toward building more green buildings including single-family homes. Although the concern is there is not enough being done for single-family homes to make them truly green? Homes are being built with ENERGY STAR appliances added and called green. Indeed, this is not green. Green needs to include water conservation, use of solar and wind energy, wise us of on-site resources and thought developed at the design stage. The research does indicate that a green home can be built and be very sustainable even in colder climates. Ten of the fourteen homes in the research are from northern climates. This is very encouraging for the future of green single-family home construction.

The thesis did not investigate to any significant level cost factors of building green. It seems that green construction is more costly in terms of construction but less costly long term in energy and building maintenance. The cost factors of building green and its associated impact on the carbon footprint would be an additional interesting research topic.

Education is another element that appears to be lacking. Based on the research data, education provided at the sites examined is minimal or does not exist. Another level of concern is educating the general population about sustainability, what it is and how it impacts the global community. Learning about sustainability, its impact and everyone's responsibility, needs to be elevated to the same level as learning to read and write. Through greater understanding society can begin to become sustainable.

While much has been done, especially in the last few years to improve the sustainability of building, much remains to be done. Energy was a significant driver in each of the structures in the study group. There needs to be more incentive programs that encourage building owners to incorporate elements such as solar power and heating, wind turbines, geothermal heat sources, green roofs. There also needs to be better and more environmentally friendly insulating techniques, water use and conservation measures along with all the other green technologies available. Overall, a "holistic" approach to building design, construction and operation is warranted.

7.1 Implication for the EHS Professional

An interesting aspect of the thesis research is its implication to the Environmental, Health and Safety (EHS) Professional. My experience in EHS has focused in the industrial and consulting fields in small and medium sized companies. The focus as such has been on compliance and related EHS issues and to a far less degree the green impact of a business operation. The EHS Professional can actually do considerable more by branching out to more aspects such as energy consumption and the related carbon footprint that a business has on the global community as a whole. The EHS Professional needs to move beyond the traditional roll and work with corporate staff in developing a sustainability program. Such a program should be as common in even small and medium businesses as the traditional environmental programs or ISO (International Standards Organization).

APPENDIX A – Buildings Surveyed

ID Number	Building Type	Location	Building Owner	Rating Type		Rating Results					
				Type	Rating	Site	Water	Energy	Materials	Indoors	Innovation
1	Office	Washington, D.C.	National Ass. Of Realtors	LEED	Silver	9	4	5	3	7	5
2	Office	Providence, R.I.	Save The Bay Center	no							
3	Office	Overland, Missouri	Alberici Corp. Offices	LEED	Platinum	12	5	16	9	13	5
4	Office	Little Rock, Arkansas	Winrock International	LEED	Gold	6	4	9	6	13	5
5	Office	Little Rock, Arkansas	Heifer International Center	LLED	Platinum	12	5	12	6	12	5
6	Office	Portland, Oregon	RIMCO: OHSU Medical Group	LEED	Platinum	13	5	14	8	10	5
7	Office	Stanford, Calif.	Carnegie Institute	no							
8	Office	Berkeley, Calif.	U.S. Dept. of Energy	LEED	Platinum	7	3	9	6	9	5
9	Office	Boise, Idaho	The Christensen Corp.	LEED	Platinum	13	5	12	6	10	3
10	Home	Rockland, Calif.		LEED	Certified	4	2	14.5	5	6	0
11	Home	Freeport, Maine	Mort & Evelyn Panish	LEED	Silver	10.5	1	15.5	5.5	10	4
12	Home	Westwego, Louisiana		LEED	Platinum	17	8	24	8	14	5.5
13	Home	San Diego, Calif.		LEED	Platinum	10	4	17	9	14	5
14	Home	Gainesville, Fla.		no							
15	Home	Boulder, Colorado	John & Vicky Graham	no							
16	Home	Boulder, Colorado		no							
17	Office	Boulder, Colorado	Nature Conservancy	no							
18	Home	Charleston, R.I.		no							
19	Home	Boulder, Colorado	Barrett residence	no							
20	Home	Kerhonkson, N.Y.	Judith Karpova	no							
21	Home	Evanston, Ill.		no							
22	Home	Chicago, Ill.		no							
23	Home	Santa Monica, Calif.	Steve Glenn	LEED	Platinum		LEED	score	not	provided	
24	Home	Glenville, N.Y.		no							
25	Office	Washington, D.C.	Naval Engineering Command	no							
26	Office	Denver, Colorado	EPA Region 8 Offices	LEED	Silver		LEED	score	not	provided	
27	Home	Tukwila, Wash.		no							
28	Home	Venice, Calif.	Angela Brooks	no							
29	Office	Chelmsford, Mass.	EPA New England Lab	LEED	Silver		LEED	score	not	provided	
30	Office	Arlington, Va.	General Services Admin.	LEED	Gold		LEED	score	not	provided	

APPENDIX A – Building Surveyed

Site Number	Building Type	Location	Building Owner	Sq Ft	Date Complete	Cost	Architect	General Contractor	Info Source
10	Home	Rockland, Calif.		2,543	Jan-07	$ 128 K			3
11	Home	Freeport, Maine	Mort & Evelyn Panish	2,250	May-06	$ 625 K	CJ, Taggart Const.	Peter Taggart	3
12	Home	Westwego, Louisiana		3,860	Apr-08			Deltec Homes	3
13	Home	San Diego, Calif.		3,000	Jul-08		Fullerton Architects	Standard Pacific Homes	3
14	Home	Gainesville, Fla.		4,500	Mar-08	$ 190 K		GW Robenson	4
15	Home	Boulder, Colorado	John & Vicky Graham	1,700			AJ DAJ Design	Doub Building Inc.	5
16	Home	Boulder, Colorado		2,574	Jan-03		Markel Homes	Markel Homes	6
18	Home	Charleston, R.I.		2,600	Mar-04		Earthrise		7
19	Home	Boulder, Colorado	Barrett residence	2,500	Jan-01		Barrett Studio	Dominique Arch.	6
20	Home	Kerhonkson, N.Y.	Judith Karpova	1,100	Jan-05	$19/sq. ft.			7
21	Home	Evanston, Ill.		4,000	Jun-03				7
22	Home	Chicago, Ill.		1,830	Aug-03	$ 145 K			7
23	Home	Santa Monica, Calif.	Steve Glenn	2,480	Aug-06		Living Homes, LLC		8
24	Home	Glenville, N.Y.		4,500	Jun-08	$ 429 K	Glenn Gibbons	Lifetime Home Building	9
27	Home	Tukwila, Wash.		2,100				Greenlight LLC	11
28	Home	Venice, Calif.	Angela Brooks	1,790	Apr-05	$ 270 K			12

APPENDIX A - Buildings Surveyed

Site Number	Building Type	Location	Building Owner	Sq Ft	Date Complete	Cost	Architect	General Contractor	Info Source
1	Office	Washington, D.C.	National Ass. Of Realtors	100,000	Mar-04	$ 46 M	GUND Partnership	Lawrence Brandt	1
2	Office	Providence, R.I.	Save The Bay Center	15,000	Mar-04	$ 5 M	Croxton Collaborative	Agostini Const.	2
3	Office	Overland, Missouri	Alberici Corp. Offices	110,000	Mar-04	$ 21 M	Mackey Mitchell	Agostini Const.	1
4	Office	Little Rock, Arkansas	Winrock International	24,000	Mar-04	$ 3.9 M	HOK	Nabhoiz Corp.	1
5	Office	Little Rock, Arkansas	Heifer International Center	94,000	Mar-04	$ 18.9 M	Polk Stanley	CDI Contractors	1
6	Office	Portland, Oregon	RIMCO: OHSU Medical Group	262,000	Oct-06	$ 160 M	GBD Architects	Hoffman Const.	2
7	Office	Stanford, Calif.	Carnegie Institute	10,890	Mar-04	$ 4 M	EHDD Architecture	DPR Const.	2
8	Office	Berkeley, Calif.	U.S. Dept. of Energy	95,690	Mar-06	$ 52 M	SmithGroup	Rudolph & Sletten	2
9	Office	Boise, Idaho	The Christensen Corp.	195,000	Jul-06	$25 M	HDR. Inc.	Russell Corp.	3
17	Office	Boulder, Colorado	Nature Conservancy	16,000	Feb-02		Oz Architecture	Deneuve Const.	6
25	Office	Washington, D.C.	Naval Engineering Command	156,000	Jul-98	$ 21 M	Shalom Baranes	Sherman Smoot	10
26	Office	Denver, Colorado	EPA Region 8 Offices	248,849	Nov-06	$ 90 M	OPUS A&E		10
29	Office	Chelmsford, Mass.	EPA New England Lab	72,000	Jun-01	$ 18.3 M	Bernard Johnson	Erland Const.	10
30	Office	Arlington, Va.	General Services Admin.	654,000	May-06		Crescent Resources		10

APPENDIX B, Part One – Detailed Element Descriptions

Site Number	Detailed Element Descriptions Innovation/Design	Location	Sustainable	Water
1	Chilled beams, under-floor air distribution, use of trellis at the roof for sun control.	Adjacent bld. Shades west side Use of native plants.	To reduce heat island effect plantings are used.	10K cistern collects rainwater, waterless urinals, use drought resistant plants on terrace
2	Building partially buried, w/roof covered with vegetation for cooling, also allows most of the bld. To blend in w/natural surroundings	Overhangs provide shading on south side of building	Roof is partially covered in vegetation.	Water savings plumbing & waterless urinals. Rainwater is captured from parking lot & used for irrigation
3	Open interior for interaction, installed white-noise system & sound-absorbent materials to absorb noise.	Located offices to orient towers south for greatest use of daylight.		Retention ponds & wetlands treat stormwater on-site, rainwater from garage is collected & used in the cooling tower. Water efficient fixtures reduce use by 500K gal./yr.
4	Gull-wing roof, to keep out sun and collect rainwater.	Used a narrow site plan	Site collects more rainwater than can be used for irrigation. Excess is used by nearby marina. Use of mature trees already on-site to provide shading.	Rainwater is collected in a cistern located under the building, overflow goes to a nearby underground reservoir. City would not allow use of rainwater for toilets.
5	Staircase & wetland design are part of the bld. & used together w/ventilation system to cool bld.	Revitalized a contaminated site in a less desirable part of the city	Used only native plantings and on-site materials for sit & bld. Construction.	Stormwater runoff is collected in an on-site wetland lined with clay from the site itself. A 3K gal. tower collects rainwater from the bld., & a separate greywater tank are used toilets. Together they supply 90% of water needs. Waterless urinals are used.

Site Number	Detailed Element Descriptions Innovation/Design	Location	Sustainable	Water
6	Use of stairways (or towers) on each side of the bld. To move air& heat up and out.	Site located next to new streetcar line & existing aerial tram to take advantage of public transportation.	The roof area is a large greenhouse which reduces heat buildup in the building.	Rain & storm water are collected from all surface area on-site & used along w/ a bioreactor for irrigation of toilets and radiant cooling. This reduced freshwater demand by 68% or 2.1 million gal. yearly. Basement cisterns collect water runoff & greywater.
7	Central cooling tower uses droplets of water sprayed into air to cool rising air, the cooled air sinks to bottom of tower and used to cool bld.		Bld designed around existing stand of mature oak trees in order to preserve them.	there were no specific water reduction measured noted in the article
8	200-acre hilly site, used floors that overhang each other to create space & reduce need to disturb the site.		80% of the construction waste was recycled. Use of bicycle racks and natural landscaping of native plants.	Waterless urinals & & low flow faucets are used.
9	Use of stormwater from City streets & parking lots for water use.	Bld. Located near public transportation & parking facilities	Bld. Placed near public transportation.	Bld. uses 60 - 80% less water by collecting stormwater from Boise streets & parking lots & its own greywater to flush toilets & urinals. Low water use toilets & urinals.
10		Part of a planned community including schools that will minimize transportation needs.	Builders recycled 75% of site waste.	
11	Home built w/ roof oriented toward south for solar advantage. Advanced framing used to increase insulation value to R27.	Located on a reclaimed sand pit that reduced zoning & excavation requirements.	Located on a reclaimed sand pit, that reduced zoning needs. Also used existing site vegetation & trees which minimized site disturbance & erosion.	Stormwater management system controls water runoff.

APPENDIX B, Part One – Detailed Element Descriptions

Site Number	Detailed Element Descriptions Innovation/Design	Location	Sustainable	Water
12	Used lot from existing home destroyed by Hurricane Katrina.		Used permeable turf to allow 85% of rainwater to filter into the ground.	
13	Innovative use of on-site materials for construction including vegetation.	Site selected as part of existing community & preserves local history	Minimal disruption to existing site. Use of building material from other sites, on-site stone & vegetation used in flooring	Use of native plant species reduced irrigation demand by at least 71%. Dual-flush toilets & tankless water heaters are used.
14	Part of CobbleField home development w/265 homes. Uses circulating loop hot water heater provides hot water immediately & saves water.	Won over opposition to project by incorporating minimal site disruption.	Use of existing trees & native vegetation. Construction debris was recycled not land filled.	Irrigation system uses recycled water & circulating loop hot water piping.
15	Added 700 sq ft to existing home & made entire home green		Removed natural gas lines & need to use outside energy source thus reducing carbon impact to society	Dual-flush toilets
16		Located on public transportation route, & part of an existing development	Construction waste was 62% recycled.	Drip irrigation installed
17		Redesign of an existing structure into office space	Use of bamboo for flooring as a natural, renewable resource. Natural oils were used for finishing the woodwork.	
18	Home is not connected to the local power grid, produces own electric power.		Cut only trees needed for home, natural vegetation used. Most of site has been allowed to return to natural state.	rainwater collection system & is used for irrigation.
19		Built in a community development on land already slated for home construction.	Use on native plants.	Low flow toilets reduce water use 40%.

APPENDIX B, Part One – Detailed Element Descriptions

Site Number	Detailed Element Descriptions Innovation/Design	Location	Sustainable	Water
20	This was an existing home renovated to reduce energy use. A geothermal closed loop geothermal system is unique for a north/east home.	Built in 1979, located on a hill top lending itself to renewable energy technologies. Home is aligned North/South which allows max. use of sun.	No impact on existing site. Existing deep well provides water for geothermal system. Two other wells shallow & dry receives discharge water.	All hot water comes from the geothermal system & is stored in an insulated tank.
21		Located on Lake Michigan, minimal site disturbance & view important to homeowner.	Used on-site materials such as stone for sidewalks.	
22	Modular design to allow off-site assembly, open floor plan to accommodate ventilation system. Has a green roof to absorb stormwater.	Urban area w/empty lots, near mass transit, schools & other family related needs.	Created in a family oriented area to help encourage green home bld. & improvement	Stormwater is absorbed through a green roof.
23	"Six Zero" concept used meaning zero: waste, energy, water, carbon, emissions & ignorance		Use of native plants	Green roof absorbs rainwater & reflects heat.
24	Design of home took 2 major factors into consideration, 1. used NAHB standards, 2. universal design (for use of all age groups).	House located on site w/southerly orientation to take advantage of sun. Trees provide summer shade but let light in during winter.	Built w/ minimal disturbance to site, using natural vegetation & on-site trees.	Rainwater collected in cistern used for irrigation.

APPENDIX B, Part One – Detailed Element Descriptions

Site Number	Detailed Element Descriptions			
	Innovation/Design	**Location**	**Sustainable**	**Water**
25	**Bld 33 is an existing bld renovated as green office space**	**Bld. Site had contamination that was cleaned up first before construction started.**	**Because of its historic significance the façade. Construction materials were recycled.**	**All plumbing is low-flow to conserve water use.**
26	**Used project team to design green into bld. Had to be designed to fit historic requirements of area.**	**23 floors separated by 2 towers. Easy access to public transportation & bicycle riding**	**Designed to accommodate solar use & air flow. Construction material recycled & equipment required to use biofuel.**	**Green roof collected rainwater. Low flow fixtures are used.**
27		**Home built within 1/4 miles of public transportation.**	**Used at least 30% of existing trees on site, & native plants for landscaping.**	**No potable water used for irrigation as stormwater is collected.**
28	**Challenge redesigning a 1923 bld. Making it green & keeping original design. The major design feature is the shading solar canopy.**	**Location allowed owner to take advantage of the Southern, Calf. Sun.**	**Solar power provides most electrical needs, excess is sold to the main power grid. Much of the existing bld. Was reused in some way saving resources.**	
29	**One main design criteria was that all materials had to be from on-site, or recycled.**	**Location on a hilltop provided drainage and cooling effects of prevailing winds.**	**Site was selected for available use of natural resources, trees, & slops. On-site soil & plants used for final landscaping. On-site rock was crushed & used in construction.**	**Low water use fixtures**
30		**Environmental responsible location used contaminated rail yard that was cleaned up before construction.**	**Located near major airport & public transportation. Built on former rail yard saving natural sites. There is a dedicated recycling area for occupants to use.**	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions			
	Energy/Atmosphere	Material/Resources	Indoors	Awareness/Education
1	Annual Co2 is 19lbs/sq. ft reduce 50% in 2 yrs. Purchase energy from wind power. Energy use is 51,300 KBT/ft2, photo sensors used. HVAC management program.	Use of recycled granite, & recycled carpet content,	Interior shades provide comport & lighting control, lighting fixtures placed to avoid light pollution,	
2	Use of heater/chiller boiler that uses no refrigerants for cooling. Zoned w/sensors & local temp. control. Roof top solar panels provide electricity.	Cellulose wall insulation, VOC free paint, high percentage of recycled content in finishes	Daylighting is used thru skylights, sail cloths are used to reflect light from ceiling	
3	On-site wind turbine & solar heating system combine to meet 20% of the energy demand. Sensors used to control lighting. A heat-recovery mechanical system	Heavy insulation in envelope	Daylighting is used thru skylights. Oriented offices along southwest side to allow for Daylighting. Installed	
4	Extensive roof in a "V" shape covers the entire building providing shade. Under-floor air distribution & separate controls allow individual office to control temp.	Original design was all glass but changes to opaque siding, which reduced cost and allows natural light in. Used local material sources & structural materials made from 75% recycled materials.	Daylighting is used in all occupied spaces.	
5	Use of wetland design & air flow system cools bld. Reducing energy use by 35%. Use of controls from daylighting have significantly reduced energy & cooling demands. Under floor air flow used to control heat via sensors.	97% of materials from former build. On-site were recycled, most used in construction of new building. All materials were bought w/n 500 miles, most in Little Rock.	Daylighting used throughout bld. w/sensors monitoring intensity of light. Window shading is used along the bld. Entire south side reducing energy demands.	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions			
	Energy/Atmosphere	Material/Resources	Indoors	Awareness/Education
6	Bld. Mostly glass exterior, required innovation air flow to remove solar heating. Open staircases used to lift air up and out. Enhanced by air flow system & controls that bring in cool air from the north side of bld. Solar cells are built into out side glass walls to provide electricity.		Daylighting used through the glass walled bld. Outside glass walls are shaded & controls automatically open and close shades based on amount of light being received.	
7	Lobby cooled by chilling tower, & is spayed on the roof at night to cool and release heat & stored in insulated tank, saving on energy costs. General bld. heating & cooling accomplished through floor piping. Vents used to circulate air, controlled automatically.	Most of the siding, casework, sinks & faucets were reused from existing on-site structures. All other material bought from local materials exchange. Used low impact materials to reduce carbon emissions associated with construction materials.	Daylighting an feature to capture natural light, open interior space w/open-panel for private meetings. Bifold doors open to courtyard & landscaped area.	
8	Energy use is monitored through on-site measurement that controls temperature in the bld.	Used bamboo flooring & FSC certified woods, low-VOC carpet, paints, sealants and adhesives were used.	Outside air provided for building ventilation. Daylighting is sued throughout the bld.	
9	Uses geothermal heating, smart lighting & under floor air vents for cooling. This reduces energy demand by as much as 50%.	Low VOC materials were used.	HVAC system provides hourly air exchange for fresh air and comfort of occupants.	A "knowledge" wall is provided on-site to educate occupants & community.
10	Electricity is supplemented w/ photovoltaic roof tiles reducing electric needs by as much as 70%. A variable speed furnace w/a 94% AFUE rating (losing only 6% of heat through chimney).	Low emission windows, attic insulation w/heat resistance, exterior bld. Wraps to prevent heat/cold from escaping.	Indoor air quality is enhanced by control system that provides fresh are as needed.	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions			
	Energy/Atmosphere	**Material/Resources**	**Indoors**	**Awareness/Education**
11	**Electricity is supplemented w/ photovoltaic roof tiles reducing electric needs. Roof overhangs provide sun protection. Floor tiles allow radiant heat from sun to be stored.**		**Daylighting is used w/strategically placed windows. Home meets ENERGY STAR rating for indoor air quality.**	
12	**Switches installed to allow control of internal lighting.**	**All appliances including HVAC is HERS (Home Energy Rating System) rated, reducing energy use by at least 38%. There are 3 separate water-heating systems for 3 zones to minimize water travel distance. ENERGY STAR windows & appliances are also installed.**		
13	**Electricity is supplemented w/ photovoltaic roof tiles reducing electric needs by an estimated 31%.**	**Built w/timbers from a discarded pier in Portland. Stones reclaimed from site & used in building.**		
14	**HVAC w/fresh air intake, dehumidification and local controls. Radiant barrier in roof reflects 95% of heat & keeps attic 30% cooler. All appliances & HVAC are ENERGY STAR approved.**	**R30 fiber blown cellulose insulation was used.**	**Low VOC materials, cellulose insulation & coated ductwork to prevent mildew. Natural lighting & heat protection from double-pane windows.**	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions			
	Energy/Atmosphere	Material/Resources	Indoors	Awareness/Education
15	Added a renewable energy solar system that provides 130% of power, to roof that supplies hot water & radiant heating system in floor. Also produces electric, excess of which is sold back to power grid. EPA wood burning stove was added.	R70 roof rating was achieved w/ cellulose insulation, also used in the walls.	Skylight & motorized windows added to manage fresh air flow, controlled by sensors. Low VOC paints & stains were used.	
16	Windows are double-pane. R-38 insulation in roof, R-13 in walls. 93.6% efficient furnace w/programmable thermostat	Insulation made from 90% recycled materials. Deck materials made from 100% post-consumer materials.	PVC piping installed under the slab w/exhaust for radon gas. Low VOC paint used on all interior surfaces.	
17	Operable windows allow control of air flow. Motion detectors turn lights on when needed. Wind power is used to reduce energy demand 20%.	bamboo flooring used in high traffic areas, finished w/low VOC treatments.	Enlarge windows on first two floors to increase daylighting. Decrease windows on third floor to decrease afternoon heating. Reflective ceiling maximizes sunlight.	
18	South facing house for maximum solar use, natural shading used on south side. Solar heating used to heat water and produce electricity.	All wood purchased from FSC sources. Use of advanced framing reduced amount of material needed.	Skylights used to increase daylighting. Water based finishes used on all surfaces, natural stack ventilation w/auto roof mounted skylights that open in summer months. Radon evacuation system in sub-flooring.	
19	Windows treated w/ an E film that keeps heat out in summer/in during the winter. All appliances are ENERGY STAR rated. Cellulose insulation used in ceilings & walls.	Used local materials & recycled polystyrene. Cork used for flooring comes from the bark of oak tree used because of durability & absorbs sounds. Low VOC coating used.	Daylighting is used through windows. E film lets light in while keeping heat out.	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions Energy/Atmosphere	Material/Resources	Indoors	Awareness/Education
20	Heated w/geothermal heat pump powered by solar panel installation on roof. These both heat & cool. Old insulation removed in attic & replaced with 1/2" foam.	All lighting was replaced w/compact fluorescent bulbs & motion sensors.	Use of foam insulation brought attic inside air cooled part of home, improving air quality & reducing energy costs.	
21	Electricity is supplemented w/ photovoltaic system on roof reducing electric needs by an estimated 80% also provides hot water for domestic use & radiant-floor heating system.	All materials were FSC certified.	Daylighting used throughout w/high performance windows.	
22	Solar chimney to move warm air up and out through natural vents. Heated w/gas-fired boiler.	Use of low impact materials such as fly-ash concrete, cork floors, carpet made from recycled soda bottles,, low-VOC paints & cellulose insulation made from recycled paper.	Daylighting accomplished through windows placed to allow max sunlight in.	
23	Used thermal chimney & natural ventilation for cooling. A photovoltaic system on the roof generate electricity & heat water.		Daylighting used as are moveable wall partitions to create more space.	
24	Heated w/water based boiler w/piping in flooring. Arxx walls are air tight & increase R value to 50, reducing energy use by 30%. All appliances are ENERGY STAR rated.	Used insulated concrete forms made from recycled materials. All materials are from local suppliers & made from recycled materials.	Daylighting achieved through windows and skylights. Radon evacuation system located in basement sub-floor. All entrances are at grade w/no steps.	

Site Number	Detailed Element Descriptions			
	Energy/Atmosphere	**Material/Resources**	**Indoors**	**Awareness/Education**
25	**roof & walls insulated, added super windows for energy efficiency & daylighting. Occupancy sensors used to control lighting. Campus steam system provides heat. Air circulation system helps cool structure & reduce electrical demand.**	**All construction materials made at least partially from recycled products & low-VOC products used.**	**Daylighting used extensively. Wall panels used to provide noise control.**	
26	**Reduced energy use by 30%. Exterior sun shades used to lower direct sunlight to interior & save energy costs. Green roof added to reduced cooling requirements. Solar panels on roof produce electricity. An automatic ventilation system controls air flow for heat removal through under-floor air distribution system.**		**Daylighting used throughout, ventilation system provides fresh air. Carbon-monoxide controlled parking ventilation. Individual office temp. controls provided for occupant comfort.**	
27	**Solar hot water system, radiant slab heating. Used on-demand hot water heating system & ENERGY STAR appliances.**	**Used FSC certified wood products. Used no vinyl products, recycled materials used as much as possible. Low-VOC paints were used.**	**Daylighting used to reduce electrical demand & provide lighting. House vented with fans**	

APPENDIX B, Part Two – Detailed Element Descriptions

Site Number	Detailed Element Descriptions Energy/Atmosphere	Material/Resources	Indoors	Awareness/Education
28	Canopy contains photovoltaic panels to transform sunlight to provide 95% of the electricity needs. Also protecting the main structure from the heat. Heat provided through concrete floors from solar hot water heaters in canopy.	As much as the existing bld. was reused reducing cost & saving resources	Daylighting provides lighting w/ minimum use of supplied lighting which is controlled by sensors.	
29	Energy systems include gas-fired boiler, water-cooled chillers, daylight dimmers, low-E windows managed thru an energy management system. A solar awning provides electricity to the bld.	Concrete was made using fly-ash, framing steel was 85% recycled materials, gypsum board used for insulation is 105 recycled etc. Low-VOC paints were used.	Daylighting, from windows, solar tubs, and skylights, w/ sensors control lighting. Interior circulation system is automatically controlled & provides 100% outside air.	
30	High-performance windows reduce solar gain & natural provide lighting. An internal energy management system monitors heating & cooling loads for comfort & efficiency.	Purchase of materials followed EPA guidelines. Alternate to vinyl products & low-VOC paints & adhesives were used. Wood-based materials are FSC certified. 63% materials were regionally produced.	Use of low-emitting materials & ventilation system designed to provide fresh, clean air.	One requirement was a User Education Program, signage placed through-out the bld. To inform occupants & visitors about the bld.

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